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Stumping & Pushover Logging
in the
Nelson Forest Region
1992 & 1993 Soil Disturbance Surveys

G. Davis, M.Sc., P.Ag.
W.H. Wells, P.Ag.

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Technical Report TR-009

forest sciences

NELSON FOREST REGION

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Technical Report TR-009

Forest Sciences Section
Ministry of Forests
518 Lake Street
Nelson, B.C.
V1L 4C6

December, 1994

EXECUTIVE SUMMARY

Armillaria ostoyae (Romagn.) Herink has been identified as a serious pathogen that reduces timber productivity in the Nelson Forest Region. Preliminary research indicates that increased timber production can be achieved through stump removal on some sites (Morrison *et al.* 1988). The efficacy of root removal in controlling *Armillaria* is attributed to the removal of infectious root material and potential long-term food sources, i.e., stumps and large roots (Morrison *et al.* 1991).

Prior to the widespread implementation of this new site treatment, it is imperative that proposed treatment benefits are reviewed within the context of benefits to and/or impacts on ecosystem function and diversity, on a site sensitivity basis. The soil resource is one of the more obvious ecosystem components potentially affected by stump removal treatments.

This report presents soil disturbance surveys from 19 stumped and pushover logged (PO) treatment units surveyed in the Nelson Forest Region during 1992 and 1993. Discussion topics include future requirements for: characterizing stump hole disturbance; soil disturbance surveys; and, testing and revising the *Interim Guidelines for Armillaria Management in the Nelson Forest Region - Soil Sensitivity Considerations*. The following briefly highlights the key findings and recommendations of the report.

General

- Stumping and PO logging created stump holes, non-stump-hole mechanical site preparation disturbances (particularly wide gouges and wide scalps), and timber harvesting disturbances.
- The level of total potentially detrimental soil disturbance associated with stump removal treatments was highly variable ranging from low (10% of the net area to be reforested, or NAR) to very high (41% of NAR).

Stump Hole Soil Disturbance

- The percentage of NAR occupied by stump holes varied considerably between treatment units, ranging from 5.1 to 19.6.
- In general, stumping resulted in a greater percentage of NAR occupied by stump holes than did PO logging, reflecting, in part, the larger area of stump holes associated with this treatment.
- Most stump holes (>80%) were not filled with plantable mineral deposit.
- Stump hole areas (1 m^2 to >5 m^2) were comparable to, or exceeded, those of timber harvesting and mechanical site preparation (MSP) disturbances considered potentially detrimental as a result of compaction and/or soil disturbance.
- Existing MSP disturbance categories poorly described stump holes; a separate soil disturbance category is required to quantify and characterize stump hole soil disturbance.

Total Potentially Detrimental Disturbance and Total Soil Displacement (Based on More Restrictive Definition)

- As a percentage of NAR, total potentially detrimental disturbance generally decreased in the following order: summer PO ≅ stumped > winter PO.
- Differences in total potentially detrimental disturbance between treatments reflected the relative abundance of MSP (stump hole and non-stump-hole MSP) and timber harvesting disturbances. Stump hole disturbance was comparable between summer and winter PO (averages 8.3% and 10.5% of NAR, respectively) and was slightly higher for stumped treatments (average 14.4% of NAR). Non-stump-hole MSP disturbances were common to both summer PO and stumped treatment units. Timber harvesting disturbances were most common on summer PO treatment units.

- In 1993, based on the more restrictive definition of total potentially detrimental disturbance:
  - three of 11 treatment units met the *MSP Guidelines* maximum of 13% of NAR. This included one summer PO and two winter PO treatment units (mean value and LCL (90%))
  - five of eight PO and two of three stumped treatment units met a total potentially detrimental upper limit of 20% of NAR (LCL (90%)).
  - none of the stump removal treatments met a total potentially detrimental disturbance of 6% of NAR
- All three stump removal treatments met a total soil displacement of 30% of NAR, when the total potentially detrimental disturbance was not noticeably high; very few treatment units met a total displacement of 15% of NAR.

Future Information Needs

The following information is needed on well-planned and -executed treatments

- quantification and characterization of stump hole size and distribution over a range of site, soil and stand characteristics in order to define potentially detrimental disturbance specific to stump holes; and,
- soil disturbance data on treatment units encompassing a range of site and harvesting factors (e.g. season, equipment, and soil and stand characteristics) in order to define "achievable" total potentially detrimental disturbance.

Recommendations

1. Phase in the implementation of stump removal as an operational tool to allow time for additional surveys, evaluation, and training of operators and soil disturbance surveyors.

2. Develop a formalized Regional soil disturbance survey program to coordinate and summarize soil disturbance monitoring on:
   - a minimum of 20 to 30 PO and five to 10 stumped operational benchmark treatment units in 1994/95, encompassing the range of site and soil factors specified in the *Armillaria Soil Sensitivity Considerations*;
   - designated operational trials on treatment units with slopes 30% to 45%, and high forest floor and erosion site sensitivity hazards; and,
   - designated operational trials to evaluate options available for rehabilitating stump holes, e.g., spot filling or re-contouring on low sensitivity treatment units (e.g., L forest floor and displacement hazard ratings).

3. Create a soil disturbance category specific to stump holes, with size variants, and undertake systematic documentation of stump hole dimensions by size variant in the 1994/95 surveys.

4. Implement the following rules for stump removal operations (non-designated trials) over the next two years:
   - strict compliance with *Armillaria Soil Sensitivity Considerations*, with the one exception of no treatment on sites with an H mass wasting hazard;
   - preference given to winter over summer PO logging on sensitive sites;
   - preference given to PO logging unless there are specific concerns (e.g., operator safety) which would dictate the use of stumping;
   - restricted movement of stumps on site to reduce soil displacement;
   - pre-work conferences to discuss site sensitivities with operators; and,
   - routine reconnaissance surveys during operations to identify potential problems early on.

5. For operational treatment units designated for stump removal in 1994/95, consider approving PHSP total* potentially detrimental disturbances of up to 20% of NAR during harvesting, with the requirement to

rehabilitate skid roads post-harvest. The PHSP post-harvest maximum would be the 20% of NAR minus anticipated gains from rehabilitation as shown on the logging plan. The objective will be to reduce the total potentially detrimental disturbance as close to 13% of NAR as possible. The maximum potentially detrimental disturbance during harvesting in 1994/95 should be reviewed prior to the 1995/96 field season based on the results of the additional surveys. A maximum of 30% or 40% total soil displacement should be used in 1994/95 depending upon the leading soil disturbance hazard, as outlined in the *MSP Guidelines*.

On designated trials (i.e., treatment units which do not meet *Armillaria Soil Sensitivity Considerations*), the maximum allowable potentially detrimental soil disturbance should be reviewed by the Regional soil scientist on a site specific basis.

6. Review the following items based on the Regional 1994 and 1995 soil disturbance surveys:
   - disturbance categories used to characterize stump removal disturbance;
   - dimensions and categories considered "potentially detrimental" or excessive;
   - potential trade-offs of stump removal in terms of organic matter, nutrient and habitat losses, by biogeoclimatic subzone and site series;
   - site sensitivity rules in the *Armillaria Soil Constraint Guidelines*; and,
   - options to lower the PHSP total potentially detrimental maximum through planning and/or rehabilitation.

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1.0 INTRODUCTION

In southern B.C. *Armillaria ostoyae (Romagn.) Herink* has been identified as a serious pathogen that reduces timber productivity in several biogeoclimatic zones (Morrison *et al.* 1991). In the Nelson Forest Region (NFR), the control of this pathogen is an important management issue. In 1993 the *Interim Guidelines for Armillaria Management in the Nelson Forest Region* (NFRS 1993) were finalized. These interim guidelines outline various site specific treatment options to control *A. ostoyae*, including post-harvest stumping and/or pushover logging (PO). The efficacy of these root removal treatments in controlling *Armillaria* is attributed to the removal of infectious root material and potential long-term food sources, i.e., stumps and large roots (Morrison *et al.* 1991).

Stump removal to control the impact of *Armillaria* on future tree growth is a form of mechanical site preparation (MSP). As with any MSP, it is important that detrimental soil disturbance from the additional treatment is limited to prevent long-term loss of site productivity (BCMF 1993a). Information on the potential effect of stump removal on the soil resource is currently limited.

This report presents the results of soil disturbance surveys completed in the NFR on 19 treatment units operationally stumped and PO logged during 1992 and 1993.

1.1 History of Stump Removal Treatments in Southern B.C.

Stump removal was explored as an *Armillaria* treatment option in southern B.C. as early as 1983. Three operational trials were initiated at that time to evaluate the costs of stumping and compare equipment productivity (Price and Hardy 1983), and evaluate resultant soil disturbance (Smith and Wass, 1984, 1991, 1994a, b). Large crawlers (e.g., D8H, D7G) were used in these studies to remove the stumps post-harvest. Two of the three trials were stumped, then root-raked and/or windrowed. The third trial was only stumped.

Soil disturbance surveys undertaken on the three trials by Smith and Wass (1984, 1991, 1994a) showed a significant increase in soil disturbance over the adjacent control (harvested but not stumped). The majority of disturbances were shallow and moderately deep[1] deposits, shallow and deep tracks[2], and scalps.

On the one stumping trial which was not root-raked or windrowed, 14% of the net area to be reforested (NAR)[3] was undisturbed[4]. The disturbed portion of the NAR was occupied by fireguards (6.0%), skid roads (8.0%), tracks created by stump removal (26.3%), stump hole gouges (7.9%) and deposits (37.8%). Most of the stump hole disturbances were classified under the deep category. All further discussion in this report grouped gouges and tracks together.

On this site, total soil bulk densities (0-10 cm and 10-20 cm) were significantly higher for the tracks created by stump removal than for the undisturbed soil. The height and diameter of Douglas-fir seedlings growing in those tracks were significantly less than those of seedlings growing in undisturbed soil after eight years. Similarly, the heights of lodgepole pine seedlings growing in those tracks were also significantly less compared to seedlings growing in undisturbed soil.

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[1] Disturbances were classified by three depth classes (shallow: <5 cm; moderate: 5-25 cm; and deep: >25cm) and undisturbed.

[2] Tracks and gouges resulting from stump removal were combined by depth class.

[3] NAR is defined as the "total anticipated area for which basic silviculture requirements exist" (BCMF 1993a) excluding haul roads and landings. Calculations based on values in Smith and Wass 1994.

[4] Site characteristics: 19% slope, morainal terrain; calcareous silt loam soils.

A comparison of total soil bulk densities for tracks associated with stump removal versus the inner tracks of skid roads (cut-and-fill constructed) showed the inner track bulk densities to be noticeably higher[5] (Smith and Wass 1991, 1994a). Smith and Wass (1994a) also reported a greater loss in tree volume on the skid road inner tracks compared to the stump removal tracks at year eight. The authors concluded that tracks caused by stump uprooting had a lesser impact on site productivity than cut-and-fill skid roads.

The total soil bulk densities (0-10 cm and 10-20 cm) of deposits created by stump removal were not significantly different from those of the undisturbed soil, even though the mean values were slightly lower. The growth (height, diameter, volume) of Douglas-fir and lodgepole pine seedlings was not significantly different between the deposit and undisturbed disturbance categories after eight years.

Based on all three trials Smith and Wass (1991, 1994) recommended:

- limiting stumping to less sensitive sites;
- eliminating the windrowing phase and leaving the stumps in place;
- extracting the stumps with an excavator rather than a bulldozer; and,
- using sufficiently wide, rear-mounted equipment if root raking was to be undertaken.

A few stump removal trials were also initiated around this time as an option to control *Phellinus weirii (Murr.) Gilbertson* in coastal forests. In 1985, Smith and Wass (1989) undertook a comparison of soil disturbance created by stump removal using a Caterpillar D8H 275-hp tractor and a JD 792 180-hp backhoe[6]. The results indicated significantly higher disturbance on the block treated with the caterpillar compared to the excavator. The differences were largely due to the greater proportion of very deep displacement caused by the caterpillar tracks (19% vs 2% of NAR). Soil displacement created by the actual extraction of stump roots was similar between treatments (38% and 32% of NAR). The very deep displacements on both sites exceeded the existing maximum limits for harvesting operations.

In the late 1980s, the NFR Regional Pathologist undertook trials to examine the efficiency of using excavators to remove the whole tree at the time of harvesting, as an alternative to stumping. This technique was later referred to as pushover (PO) logging. These trials for the most part focused on costs and equipment productivity (DeLong 1994). While initial visual assessments indicated that soil disturbance was less with PO logging compared to stumping, limited quantitative information was collected.

Stumping and/or pushover logging have been used operationally in the NFR since 1990. Prior to 1993, fewer than 30 sites had been treated. More than 35 sites were scheduled for treatment in 1993/94 (site information provided in Appendix A) and use of this treatment is expected to increase in the future.

1.2 Current Guidelines and the Development of Future Guidelines

1.2.1 Current Guidelines

Stump removal must meet the soil protection requirement in the Silviculture Regulation (B.C. Reg. 147/88 Sec 2.1 (d)), which states that a pre-harvest silviculture prescription (PHSP) shall facilitate the protection of the soil. Stump removal is a relatively new MSP and specific information on soil disturbance is limited. Until further information is available, two documents provide initial guidance to limit site productivity losses from soil disturbance (see Appendix B). Both documents are outlined below and both use *Hazard Assessment Keys for*

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[5] Statistical significance not provided.

[6] Site characteristics: level to gently undulating morainal terrain; soils dry during treatment, no texture given; harvesting disturbances pre-stumping were comparable between blocks.

Evaluating Site Sensitivity to Soil-degrading Processes - Interior Sites (SSIWG *et al.* 1993) to evaluate site sensitivity to erosion, compaction, mass wasting, displacement and forest floor displacement.

1. *Soil Sensitivity Considerations, Appendix A* of the *Interim Guidelines for Armillaria Management in the Nelson Forest Region* (NFRS 1994)

Given the relative "newness" of stump removal treatments, the intent of the *Armillaria Soil Sensitivity Considerations* appendix is to restrict these treatments to less sensitive sites, at least initially. This will:

- permit the development of operational familiarity and expertise with these new treatments on less sensitive sites before considering them on difficult sites;
- limit potentially detrimental disturbance in the absence of information on the size and distribution of disturbances created by this treatment; and,
- restrict loss of organic matter and nutrients on nutrient limited and/or droughty soils until the potential impact of stump displacement on long-term site productivity can be reviewed.

As further information becomes available, these guidelines will be revised to provide more detailed guidance on the use of stump removal treatments based on site sensitivity and stand characteristics.

Table 1 lists the site characteristics used in the *Armillaria Soil Sensitivity Considerations* appendix to evaluate site sensitivity to stump removal operations. The underlying premise for each restriction is provided in brief. More restrictive guidelines apply to stumping than PO logging because stumping involves two entries, which increases the potential for additional soil disturbance. Also, preliminary information suggests stumping can create significant soil disturbance (Smith and Wass 1994a).

The *Armillaria Soil Sensitivity Considerations* assume well-planned and -executed operations that encompass management considerations for timber harvesting (Lewis and Carr 1989) and MSP (Curran *et al.* 1990). These guidelines are based on principles underlying the site sensitivity hazards and *MSP Guidelines*, and on field observations.

The *Armillaria Soil Sensitivity Considerations* appendix also includes draft guidelines for stump management, reflecting the importance of stumps in the ecosystem. These guidelines are very preliminary and are based on first principles.

Table 1. Site factors used in the *Armillaria Soil Sensitivity Considerations*

Site Factors to Avoid	Rationale
Slopes >30%	safety; difficulty of operations; greater potential for soil disturbance; establish baseline of expertise on less difficult terrain
Clayey Soils	limit soil displacement on stumps; limit soil compaction
Carbonates <30cm	limit soil displacement on soils with shallow good rooting medium
Unfavourable Subsoils <45cm	limit soil displacement on soils with shallow good rooting medium
Seepage <60 cm	limit treatment on wet soils where soil will be displaced with stump; limit rutting
Displacement Hazards H,VH	limit loss of nutrient and organic matter-enriched surface soil on poorer sites
Surface Erosion Hazard (H>26 points)	limit on- and off-site impacts from surface erosion in the absence of concrete information on the size and distribution of soil disturbance created by stump removal; limit potential water channeling by equipment disturbance
Mass Wasting Hazard (H>31 points)	avoid on- and off-site impacts from mass wasting in the absence of concrete information on the size and distribution of soil disturbance created by stump removal; limit potential water channeling by equipment disturbance
Forest Floor Displacement (H>19 points)	avoid loss of forest floor on sensitive sites (sites with high forest floor displacement are particularly sensitive to organic matter and nutrient losses in the form of forest floor and stumps)

2. Interim Soil Conservation Guidelines for Mechanical Site Preparation - Interior British Columbia (BCMF 1993a)

The *Interim Soil Conservation Guidelines for Mechanical Site Preparation* provide direction on limiting potentially detrimental[7] soil disturbance by:

- defining potentially detrimental disturbance categories which represent soil disturbances in excess of that required to create an improved planting spot for common MSP, and
- establishing maximum allowable levels of potentially detrimental soil disturbance and total displacement on a site sensitivity basis (BCMF 1993a).

The above steps involve an evaluation of potential "trade-offs" between soil and tree productivity losses. The first trade-off is contained directly in the definition of the potentially detrimental disturbance category. For example, in mounding, a gouge less than 30 cm deep and 0.6 m^2 is not considered potentially detrimental even though in many instances this gouge represents a less favourable growing site compared to the undisturbed soil. The less than 30 cm deep gouge is indirectly viewed as the "trade-off" for the improved growing site in the adjacent mound; only when the gouge is greater than 30 cm deep is it considered excessive and counted as potentially detrimental disturbance.

The second "trade-off" in soil productivity is the up-front maximum potentially detrimental disturbance and displacement allowed. For common MSP, these maxima represent, in part, achievable upper levels given existing operational expertise on well-planned and -executed treatments. Guideline maxima vary according to the leading soil disturbance hazard (LSDH); more stringent maxima are assigned to the more sensitive site characteristics.

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[7] The use of the term "potentially detrimental disturbance" in this report follows the 1993 soil disturbance timber harvesting and MSP soil disturbance guidelines (BCMF 1993a,b): "Soil disturbance that reduces site productivity or places other resources at risk." This includes haul roads, bladed skid roads, compacted skid trails, landings, heavily disturbed roadside work areas, bladed backspar trails, fireguards and certain MSP categories.

The total potentially detrimental disturbance maximum values in the *MSP Guidelines* are equal to the maximum values in the timber harvesting guidelines (BCMF 1993b). The underlying philosophy is that "good site preparation will not increase potentially detrimental disturbance on the site and will often mitigate detrimental disturbance resulting from harvesting activities." (BCMF 1993a). Preliminary soil disturbance results suggest that this principal may not apply to stump removal treatments.

The *MSP Guidelines* include the following provision for exceeding the Guideline maximum

> "In order to achieve other substantive management objectives (e.g., stumping to treat root rot infections...), a higher or lower level of potentially detrimental disturbance than is recommended in these guidelines may be authorized."

The intent of this provision is to accommodate specialized rather than routine treatments. To maintain long-term site productivity, the use of this provision should be restricted to non-routine, site specific cases where other options to minimize soil disturbance, such as alternative treatment and/or rehabilitation, are not feasible.

Until further information on soil disturbance associated with stump removal is available, the total potentially detrimental disturbance and total soil displacement maxima in the *MSP Guidelines* are used for purpose of discussions.

1.2.2 Future Review and Development of Site Sensitivity and Soil Conservation Guidelines for Stump Removal Treatments

Soil Disturbance

While the above two documents provide interim guidance, further information is needed:

- to evaluate and revise existing guidelines for the operational application of this treatment in order to minimize soil productivity losses, and
- to develop soil conservation guidelines complementary to the *MSP Guidelines* but specific to stump removal.

Stump removal is a unique MSP since it does not involve planned mechanical soil displacement. Soil disturbance created by stump removal is a by-product of the process. As a by-product, the dimensions, distribution and number of stump holes will vary with stand characteristics (e.g., density, distribution, diameter, site productivity) in addition to other factors which influence soil disturbance created by common MSP (e.g., operator experience, site characteristics and soil conditions). Further, soil disturbance created by stump removal is not *per se* a more favourable planting spot, although relative to no treatment the growing potential of the adjacent undisturbed soil may be improved due to a reduction in *Armillaria*[8] innoculum.

Given the nature of soil disturbance created through stump removal, the *MSP Guidelines* (i.e., disturbance categories and maximum allowable disturbance) are not directly transferable. The unplanned size and distribution of stump holes will make it difficult to define potentially detrimental, or non-excessive, soil disturbance created by stump removal.

The revision of the *Armillaria Soil Sensitivity Guidelines* and the development of stump removal soil conservation guidelines will require detailed information on treatment-specific soil disturbance levels and associated influencing factors (e.g., site, stand characteristics). Principles used to develop and refine the *MSP Guidelines* for other MSP treatments should serve as a template in developing complementary guidelines for stump removal treatments. General steps include:

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[8] Under certain cases, shallow stump holes may meet site specific MSP requirements e.g., improved moisture regime, reduced frost damage (Mitchell 1991) (Mounds are not generally produced adjacent to stump hole gouges.)

1. detailed characterization of soil disturbances created by the treatment over a range of site conditions;
2. definition of dimensions of potentially detrimental soil disturbance[9] created by the treatment;
3. definition of excessive soil disturbance to meet treatment objective; and,
4. documentation of achievable soil disturbance based on surveys undertaken on well-planned and -executed operations over a range of site and stand conditions.

Research which quantifies the "trade-off(s)" between an increase in timber production due to the control of *Armillaria* and a reduction in timber production due to stump hole specific disturbance is currently unavailable. Over the longer term, research trials addressing the above and other questions will need to be undertaken to permit fine-tuning of future stump removal soil conservation guidelines (ARWG 1994). In the interim, revisions to the ***Armillaria Soil Conservation Guidelines*** and development of stump removal soil conservation guidelines will be based on applicable MSP and ***Armillaria*** research and first principles (scientific judgment).

The above review and development process will require an evaluation of treatment "trade-offs" (benefits/impacts) not only between soil and tree productivity but also between tree productivity and other on- and off-site resources (e.g., animal habitat, biodiversity) not currently addressed in the site sensitivity hazards (e.g., erosion, mass wasting).

Stumps

The stump management guidelines are very general in nature. Further review of the potential effect of removal or displacement of stumps on their ecosystem function is required.

Stumps are important ecosystem components serving many of the same ecological functions as coarse wood debris (CWD), such as structural diversity, habitat, and sources of nutrients and organic matter (FEMAT 1993; Maser *et al.* 1988; Harvey *et al.* 1987). The recent development of CWD guidelines in the U.S. (e.g., Harvey *et al.* 1987; Eubanks 1989) and B.C. (Lofroth, pers. comm., 1994[10]) reflects a growing concern that post-harvest levels of CWD are too low on some sites and that long-term site productivity and biodiversity may be affected.

Tree biomass studies show that stumps and large roots generally represent 20-35% of full tree bole mass for medium to larger diameter trees (Johnstone 1971; Keays 1971; Young *et al.* 1964). Two studies that evaluated total stand biomass in pine stands (Johnstone 1971; Malkonen 1974) showed that, on some sites, stump and large root dry mass equaled or exceeded post-harvest CWD retention guidelines (22 to 32 mT/ha) for U.S. northwestern forests (Harvey *et al.* 1987). On a stand basis, stump plus large root mass will depend on species, site productivity, and some combination of stems per hectare, diameter and height (Keays 1971).

Conventional harvesting systems leave stumps intact in the soil. Stump removal treatments either remove stumps off-site or displace stumps above ground on-site. The potential impact of stump removal or displacement on soil productivity and other resources requires further review. The review process should address questions such as:

- how much biomass do stumps represent?
- which sites are more sensitive to loss or displacement of organic matter in the form of stumps?
- what remedial steps (e.g., rehabilitating stump holes, retaining additional CWD) can be taken to minimize the potential impact(s) of stump displacement on site organic matter and nutrient capital and on diversity of habitat?

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[9] The definition of potentially detrimental soil disturbance is based on documented losses in tree growth associated with a particular soil disturbance category, where data is available. In the absence of direct research, the definition is based on first principals (scientific judgment). For new disturbance categories, it is important that research trials are installed to verify proposed tree growth losses.

[10] E. Lofroth, Research & Development Section, Wildlife Branch, B.C. Ministry of Environment, Lands and Parks.

Appendix C provides a very preliminary review of relevant literature on the role of stumps and coarse woody debris (CWD) in the ecosystem. A more comprehensive review is required prior to revising the existing draft guidelines.

2.0 OBJECTIVES

The objectives of this report are:

1. to summarize and discuss the 1992 and 1993 *Armillaria* treatment soil disturbance surveys with respect to MSP disturbance categories (1993 only), total potentially detrimental soil disturbance, and total soil displacement;

2. to provide interim direction to District staff in assigning total potentially detrimental disturbance maximum levels on PHSPs for operational treatment units designated for stump removal; and,

3. to identify immediate research needs to characterize and quantify soil disturbance created by stump removal.

3.0 METHODS

3.1 Site Selection and Description

Candidate study sites were selected by District staff of the Ministry of Forests. In both years a preference was given to PO treatment units. In 1992, since stump removal treatments were relatively uncommon, most of the sites suggested by District staff were measured. In 1993, a larger number of treated sites were available. This permitted the selection of sites which District staff felt represented an average or better than average (i.e., benchmark) level of planning and execution.

Eight treatment units[11] were surveyed in 1992 and 11 in 1993. Surveys in both years were completed by Appropriate Forestry Services Ltd., under the direction of W.H. Wells, P.Ag., ensuring consistency in assessment between years.

In 1993, three of the 11 sites included a conventionally harvested and stumped or PO treatment unit. Soil disturbance surveys were not undertaken on the conventionally treated treatment units.
In addition to the soil disturbance survey, the following information was collected where available for each treatment unit:

- site characteristics such as soil texture, terrain, terrain complexity, slope
- soil disturbance hazards
- silviculture system
- stump removal/harvesting operations, i.e., method, equipment, pattern of skidding

3.2 Survey Methods

Surveys were completed using the standard grid point-intercept method outlined in the manual for *Measuring Soil Disturbance Following Timber Harvesting* (Curran and Thompson 1991). In 1993, a modification of this method (Curran, pers. comm., 1994[12]) was used to survey small treatment units (<5 ha); a minimum of 1,000 points were surveyed on all treatment units.

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[11] Treatment unit refers to homogeneous areas within a cutblock "that will be managed through uniform application of harvesting techniques, silviculture treatments, and stocking standards" (BCMF 1993a).

[12] M. Curran, Regional Pedologist, Nelson Forest Region, communication 1993.

The most limiting soil disturbance category was recorded for each sample point in 1992 as per Curran and Thompson (1991). For example, in the case of a 25 cm deep mineral soil deposit overlying a heavy traffic disturbance, only the latter was recorded. Using this approach, the percentage of NAR occupied by a disturbance category is only area-based for potentially detrimental, or the most limiting, soil disturbance categories.

In 1993, the need to answer questions such as the depth and distribution of deposits and gouges lead to recording all disturbance combinations at each sampling point. This permitted the calculation of area-based percentages (of NAR) for all major disturbance category combinations. In both years, however, total potentially detrimental disturbance was calculated based on the most limiting disturbance at each sample point.

3.3 Disturbance Classifications

Over the two-year study period, timber and MSP soil disturbance categories were revised. The most current categories were used in each year of the soil disturbance surveys. In 1993, additional soil disturbance categories were defined to better characterize and quantify disturbances specific to stump holes. Table 2 outlines MSP type categories used in each year. More detailed comparisons of soil disturbance categories between years are provided in Appendix D. To permit comparison between years, the 1993 evaluation criteria were applied to both the 1993 and 1992 surveys.

Three major differences in disturbance categories between the 1992 and 1993 surveys are of note:

1. **Definition of compaction.** During the development and revision of the timber harvesting disturbance categories, different definitions for compaction were proposed. In the 1992 surveys, soil compaction required both platiness and increased soil density. The 1993 surveys used either platiness or increased soil density as compaction criteria. Both definitions were applied to four treatment units in 1993 to develop a conversion factor for the 1992 survey results.

2. **Definition of a deep gouge.** In 1992, a deep gouge (G) was defined as an object with depth and area criteria (i.e., an object >30 cm deep within 50 cm of the sample point). However, during the surveys it became apparent that stump holes <30 cm deep and less than the area of the wide gouge (2.6 m^2) were being recorded as "other scalp" (OS). The OS category is not potentially detrimental and is intended to monitor total forest floor displacement resulting from minor scalps, not objects as large as stump holes.

   Two additional disturbance categories were added in 1993 to complement the deep gouge category (G). The criteria used to define the two additional categories were chosen to complement the deep gouge category and provide some correlation with the 1992 definition of a deep gouge. Thus, in 1993, stump holes were classified into three categories:
   - G: gouge >30 cm deep at sample point.
   - G2 (added category): gouge >20 cm at sample point and within 50 cm of a depth >30 cm; note that 1993 categories G and G2 correspond to the 1992 category G.
   - ST (added category): stump hole >10 cm deep at sample point but not meeting the criteria for G, G2 or wide gouge (WG).

3. **Documentation of scalping and/or compaction at each sample point.** In 1992, scalping and/or compaction were documented indirectly if a criteria of a disturbance category (e.g., the light traffic category provides no information on either compaction or scalping.) In 1993, the presence of scalping and compaction were recorded at each sample point to provide a more accurate estimate of total soil displacement and additional information on the characteristics of heavy and moderate traffic disturbances.

Table 2. Generalized overview of MSP type categories used in 1992 and 1993

1992 Codes	1993 Codes	Category	Definition	1993 Evaluation Criteria	
				Always Counted	Sometimes Counted
W*[1]	W*	Wide Gouge	1992 & 1993: >5 cm deep gouge over 80% of 1.8 x 1.8m	x	
	LG*	Long Gouge	1993 only: :≥ 5 cm deep gouge on 100% of 1.0 x 3.0m	x	
VW*	VW*	Very Wide Scalp	1992 & 1993: scalped on 80% of 3 x 3m	x	
G*		Deep Gouge	1992: ≥ 30cm deep gouge within 50 cm of point		x[2]
	G*	Deep Gouge (used for classifying stump holes)	1993: ≥ 30cm deep gouge		x[2]
	G2	Stump Hole	1993: :≥ 20cm deep gouge within 50 cm distance of G (≥ 30cm deep gouge)		x[3]
	ST	Stump Hole	1993: ≥ 10cm deep at point associated with gouge but does not meet G,G2 or W criteria		x[3]
WS*	WS*	Wide Scalp	1992 & 1993: scalped on 80% of 1.8 x 1.8m		x[4]
C*	C *	Continuous Gouge	1992: gouge >3m long 1993: gouge >5m long		x[5]
O*	O*	Other Scalps and Gouges	1992 & 1993: not meeting other MSP category criteria	x in total displacement	

1. * indicates "status quo" provincial categories.
2. 1993: under the less restrictive definition, always counted; under the more restrictive definition, counted if the stump hole was not filled with a >30 cm deep (D3) plantable mineral deposit; stump holes not counted as potentially detrimental were classified as low impact.
3. 1993: under the less restrictive definition, not counted; under the more restrictive definition, counted if the stump hole was not filled with a >30 cm deep (G2) or a >15 cm deep (ST) plantable mineral deposit; stump holes not counted as potentially detrimental were classified as low impact.
4. 1993: count if mass wasting hazard H; displacement hazard VH; erosion hazard VH, H; compaction hazard VH; or, forest floor hazard VH, H
5. 1993: count if mass wasting hazard H; displacement hazard VH; or, erosion hazard VH, H

3.4 Stump Hole Dimensions

Preliminary information on stump hole dimensions was collected on 10 to 20 "representative" stump holes on most treatment units for x, y and z axes. Area was calculated based on an assumed square or rectangular dimension. Since the depth of a stump hole is reduced towards the stump hole edge, 70% was arbitrarily chosen to represent a median depth upon which to base volume, rather than using the maximum depth. Volume was therefore calculated by multiplying the area by 70% of the maximum depth.

3.5 Data Summary

Because significant differences existed between the 1992 and 1993 survey results, they are discussed separately, with more emphasis placed on the more detailed 1993 survey results. The differences are as follows:

- the 1993 survey included an average or above average level of planning and execution, while the 1992 survey included an unknown level,
- the 1992 definition of compaction was more restrictive than the one used in 1993[13]; and,
- different disturbance categories were used in each year.

To improve the interpretative value of the 1992 survey results, and thereby improve comparability with the 1993 survey results, treatment unit specific "adjustment factors" were used based on the following assumptions about the 1992 surveys:

1. a portion of the 1992 moderate traffic soil disturbance (M) met criteria of the 1993 compacted heavy traffic category (Hc), based on the less restrictive 1993 definition for compaction;
2. a portion of the 1992 other scalp disturbance (OS) met the criteria of the 1993 ST stump hole category; and,
3. a portion of the non-compacted but extensively scalped moderate skidding traffic disturbance (M) represented significant forest floor displacement on two treatment units.

Further discussion is provided in Appendix E.

The percentage of NAR occupied by all major disturbance categories (timber harvesting and MSP) was calculated as outlined lined in a memo by Curran (1993). The lower 90% confidence limit (Marshall 1993; Curran 1993) was calculated for individual major disturbance categories, total potentially detrimental disturbance and total soil displacement for each treatment unit. All data analyses were undertaken in EXCEL (version 4.0). Data presentation includes summary statistics, tables and bar graphs for major disturbance categories.

For both survey years, total potentially detrimental soil disturbance was estimated using two definitions (see also Table 3):

- **less restrictive definition (status quo):** includes disturbance categories defined in the *MSP Guidelines* as potentially detrimental for the site specific LSDHs (e.g., G, WG, LG[14], WS, VWS, C). This definition includes stump holes classified as wide gouges (G) or other MSP categories irrespective of whether they are filled with plantable mineral soil[15]. The 1993 G2 and ST categories are not included.
- **more restrictive definition:** includes disturbance categories defined in the *MSP Guidelines* as potentially detrimental for the site specific LSDHs, other than the deep gouge (G). Only deep gouges not filled with plantable mineral soil are included. Similarly, the 1993 stump hole categories (G2, ST) are only included if they are not filled with plantable mineral soil.

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[13] The 1992 definition required both an increase in soil density and platiness; the 1993 definition required an increase in soil density and/or platiness.

[14] Not included in 1992.

[15] "Plantable mineral soil" refers to >70% native mineral soil to a depth of >30 cm deep for G and G2 and >15cm deep for ST.

Total potentially detrimental soil disturbance based on each definition was compared to the *Interim Soil Conservation Guidelines for Mechanical Site Preparation - Interior British Columbia* (BCMF 1993a) maximum allowable levels. Total soil displacement was calculated for each treatment unit as outlined in the *MSP Guidelines*. Treatment units (for both definitions) which met, or were in "compliance" with, the *MSP Guidelines* maxima for total potentially detrimental disturbance and total displacement are documented in the figures and a summary table. Treatment units were in "compliance" if the lower 90% confidence limit (LCL) for the total counted potentially detrimental disturbances or displacement disturbances was equal to or less than the *MSP Guidelines* maxima (NFRT 1994). Sample size did not permit subdivision beyond season and harvesting system.

Table 3. 1993 Disturbance categories and the definitions of potentially detrimental disturbance

	Less Restrictive (Status Quo)	**More Restrictive**
Counted Potentially Detrimental Disturbance		
Timber Harvesting	R,HEc,HFc,TEc,IEc,IFc	R,HEc,HFc,TEc,IEc,IFc
MSP	LG,VW,W,G[1]	LG,VW,G,(G,G2,ST)[4]
Moderate Impact Disturbances		
Timber Harvesting	HE,IE,TE,Mc,P	HE,IE,TE,Mc,P
MSP	G2,ST,(C,WS)[2]	G2,ST,(C,WS)[2]
Low Impact Disturbances	OS,(G2/D,ST/D)[3],L,M,D,B,P,X,OT	OS,(G/D,G2/D,ST/D)[3],L(E,F,Ec,Fc),HF,IF,TF,M,D,B,P,X,OT
Undisturbed	U	U

1. Gouges/stump holes with or without plantable mineral deposits.
2. Counted depending upon site sensitivity rating.
3. Gouges/stump holes with >30 cm (G,G2) or >15 cm (ST) plantable mineral deposit.
4. Gouges/stump holes with ≤30 cm (G,G2) or ≤15 cm (ST) plantable mineral deposit.

4.0 SITE LOCATIONS AND CHARACTERISTICS

Tables 4 and 5 present the following site specific characteristics for the 1992 and 1993 survey sites:

- site characteristics
- mean stump hole area and maximum depth
- site sensitivity hazard rating (PHSP and this study)[16]
- potentially detrimental disturbance categories
- 1993 interim MSP potential detrimental soil disturbance and total displacement guideline maxima
- compliance with the *Interim Guidelines for Armillaria Management in the Nelson Forest Region* (NFRS 1994)

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[16] As shown in Tables 4 and 5 differences occurred between the study and PHSP site leading soil disturbance hazard (LSDH). In some cases this resulted in a different compliance maximum. The study LSDHs are used as the reference in this report, but these discrepancies highlight the importance of accurate field assessment of the LSDHs.

Table 4. 1992 Site and harvesting information

	Donald1	**Donald2**	**ChrisV**	**Pepper Cr**	**Cathiness**	**Smallwood**	**East Fork**	**Pinnacle**
District	Golden	Golden	Boundary	Boundary	CranB	KootenayL	Boundary	Invermere
Licence No.	A34326	A34326	A18969	TFL 8	A38115	A24878	TFL 8	A18979
Cutting Permit			123	3C			3C	37
Opening/Block/Treatment Unit	OP 97	OP 98	TU2	TU3	Bk B		TU2	Bk 11
Method	ST	ST	PO	PO	PO	PO	PO	PO
Season	summer	winter	summer	summer	summer	summer	winter	winter
Equipment	D6 or equiv., ex	D6 or equiv., ex	D8 ls	ex gs	fb ex, ls or gs	ex,gs (FMC?)	ex gs	ex, (D8) ls
Skidding Pattern	desig.	desig.	desig.	desig.	rand.	desig.	rand.	rand.
No. of TU (measured)	2(2)	2(2)	3(1)	1(1)	1(1)	1(1)	1(1)	1(1)
notes on landings:	c	c	a,c	b			a,b	
Gross Cut Block Area (GCA) ha	8.7/10.2	1.5/10.2	16.5	4.4	19.5	4.2	10.2/18.5	30.3
Spur Rds & Haul Rd Area (ha)	0.24	0.1	not meas.	0.0	0.4	0.7	0.7	1.4
Landing Area (ha)	0.37/0.57	0.2/0.57	not meas.	0.4	0.4	0.6	0.5	0.6
Net Area to be Reforested (NAR) ha	7.9	1.2	5	4	18.7	2.9	9.0	28.3
Apportion of Landing to TU (ha)	0.44	0.07	na	na	na	na	na	na
Landing as % of GCA	5.1	4.5	na	na	1.9	14.1	4.7	1.9
Landing & Roads as % of GCA	7.8	11.1	na	na	4.1	30.9	11.8	6.6
Silviculture. Systems	cc	cc,left adv.reg	cc	cc	cc, st.clumps	cc	cc	cc
PHSP Designated MSP Treatment	none	none	none	none	none	none	none	none
	Donald1	**Donald2**	**ChrisV**	**Pepper Cr**	**Cathiness**	**Smallwood**	**East Fork**	**Pinnacle**
Terrain Classification System for B.C. (1980)	sgMb	Mv-Cw//D/R	gFGtl/sFGlt	sgMb/sgMv	sLw/FGt/sgFGt	fFGb/Cw/Rh/Dh	sMb-W	gMb-gFGb
Terrain Complexity	simple	concave	simple	simple	rolling	complex	simple	complex
Slope Class/Range	3/2-30	3/5-50	1/0-10	3/15-30	1/0-11	3/0-50	3/10-40	3/4-45
BEC subzone	ICHmw1	ICHmw1	IDFdm1	ICHmk1	IDFdm2	ICHdw	ICHmk1	MSdk
Site Series	04	01	04	04	01-04	01a	05-06	03-04
Forest Floor depth	8	6	5	3	8	7	6	5
Forest Floor type	hemimor	hemimor	xeromor	xeromor	hemimor	xero-hemimor	velomor	hemimor
0-30 cm Soil Texture	L-SiL-SCL	SL-SiL	fSL-LfS	SL	SiL-SiC	L	fSL-LS	SiL-SiCL
Coarse Fragments %	40	28-50	35	30	10	10	35	35
>30 cm Soil Texture	SCL	SiL	fSL-gS	SL-LS	SiC	SL-LfS	LS	SiC
Coarse Fragments %	40	50-90	>35	40	10	20-40	40	45
Stump Management	ons	ons	rem	rem	rem	rem	rem	rem
Leading Soil Disturbance Hazard (LSDH)	all M	C=M-H	C=H	all M	C=H-VH	D=M-H	C=H	D=H
Forest Floor Displacement Hazard	M	M	M	H-VH	M	H	H	H
Counted MSP Pot. Detrimental Categories	"P"	"P"	"P"	"P"+WS	"P"+WS	"P"+WS	"P"+WS	"P"+WS
MSP Guideline Pot. Detrimental Max.	13	13	13	13	13	13	13	13
MSP Guidelines Total Displacement Max.	40	40	40	30	40	30	30	30
Compliance with Armillaria Soil Sensitivity Guidelines	Y	Y	Y	N	Y	N	N	N

Table 5. 1993 Site and harvesting information

	Wetask	Chatter	Kaslo	E.Kidd	ChrisV	Colepitts	Mt7S
District	Revelstoke	Golden	Kootenay L	Kootenay L	Boundary	Golden	Golden
Licence No.	A31127	A32775	A36675	A36666	A18969	A34309	A34348
Cutting Permit No.					161		
Block\Strata\Treatment Unit	TU1	TU1	Bk 2		St A		

Method	ST	ST	ST	PO	PO	PO	PO
Season	summer	winter	winter	summer	summer	summer	summer
Equipment	ex,sc,rts	?,ex,gs	rts,ex,gs	ex,D4H	fb,gs	ex,lowhp rts	ex,lowhp rts
Skidding Pattern	rsk	dsk	rsk	rsk	rsk	dsk	dsk

No. TUs (No. surveyed)	1	2(1)	1	1	1	1	2(1)
notes on landings:		c		d			c
Gross Cut Block Area (GCA) ha	2.6	11.3	11.0	4.2	30.3	7.0	11.4
Spur Rds ha	0.04	0.05	0.27	0.05	0.33	0.09	0.88
Landings ha	0.42	0.45	0.72	0.19	2.0	0.27	0.45
Net Area to be Reforested (NAR) TU1	2.1	5.8	10.0	4.0	28.0	6.7	8.5
NAR TU2	na	5.00	na	na	na	na	1.60
Portion of Landing assigned to TU1 ha	na	0.23	na	na	na	na	0.34
% of GCA as landing +	16.0	2.0	6.6	4.4	6.6	3.8	2.9
% of GCA as landing & roads+	17.5	2.5	9.0	5.6	7.7	5.1	10.7

Silviculture Systems	cc	cc	cc	cc+str	cc	cc	cc
PHSP Designated MSP Treatment	none	none	bunch&burn	bunch&burn	none	none	none

	Wetask	Chatter	Kaslo	E.Kidd	ChrisV	Colepitts	Mt7S
Terrain Classification System for B.C. (1980)	mCvbA/sgFGt	gsFGvt/Rh	gsMb-W	gsMb-W/gFGb	gSsFG tl	SMbh	gSMvbb//Dh/Rh
Terrain Complexity	cplx	humm	humm	simple	simple	humm	humm
Slope Class/Range	2/0-15	2\0-30	3/0-60	4/36-40	1/0-5	2\5-25	2\5-55
BEC	ICHmw3	ICHmw1	ICHmw2	ICHdw	MSdm1	ICHmk1	MSdk
Site Series	01/05/06	01	01	01	04	01	01
Forest Floor depth cm	3	5	12	5	2	7	5
Forest Floor type	hemimor	hemimor	hemimor	hemimor	hemimor	hemimor	hemimor
0-30cm Soil Texture	L-SL	SiL	SiL-LS	L	fSL	SiL-SiCL	SiL
Coarse Fragment (%)	25	50	40	35	25	10	10
>30cm Soil Texture	SL	SiL	SL-LS	L-SL	fSL-LS	SiL-SiCL	SiL-SiCL
Coarse Fragment (%)	25	75	40-60	35	25	15	10

Stump Management	ons	ons	ons	rem	>50%rem	ons	onsr
Stump Hole Area (mean\SEm) m^2	5.6\1.8	10.2\3.0	4.3 \1.2	2.4 /.1	1.6 /.3	3.0 /.3	3.1/1.0
Stump Hole Volume (mean\SEm) m^3	2.2\1.0	4.3\1.8	2.2\.8	1.7/.5	.5/.1	1.1/.2	1.4/.6
no. stump holes measured	9	7		8	12	13	8

Leading Soil Disturbance Hazard (LSDH) in PHSP*	E,C=M	all=M	C=VH	E,C,Mw=M	E,C=M	C=VH	C,D,E=H
Forest Floor Displacement Hazard in PHSP	H	not given	not given	not given	not given	VH	H
Study Assessed LSDH	E,C,Mw=M	C,D=H	all=M	E=H	C=H	C,D=H	C,D=H
Study Assessed Forest Floor Displacement Hazard	H	VH	H	H	VH	H	VH
Counted MSP Pot. Detrimental Categories**	P,WS	P,WS	P,WS	P,WS,CG	P,WS	P,WS	P,WS
MSP Guideline Pot. Detrimental Max.	13	13	13	13	13	13	13
MSP Guideline Total Displacement Max.	30	30	30	25	30	30	30
Compliance with Armillaria Soil Sensitivity Guidelines	Y	N: FF,D	N: FF	N:FF	N:FF	N:FF	N:FF,D

Table 5 Continued

	Mt7W	Alki	Slewiskin	Lardeau
District	Golden	CranB	Arrow	Kootenay L
Licence No.	A34347	A19040	A20192	A30176
Cutting Permit No.		306	110	36
Block\Strata\Treatment Unit		OP 196	Bk 1B	Bk 3

Method	PO	PO	PO	PO
Season	winter	winter	winter	winter
Equipment	ex,lowhp rts	ex,rts	ex,sg	ex,rts
Skidding Pattern	rsk+dsk	rsk+dsk	rsk	dsk

No. TUs (No. surveyed)	2(1)	1	1	1
notes on landings:	c		d	
Gross Cut Block Area (GCA) ha	6.4	7.6	5.0	3.1
Spur Rds ha	0.04	0.00	0.0	0.27
Landings ha	0.08	0.43	0.0	0.18
Net Area to be Reforested (NAR) TU1	4.3	7.2	5.0	2.65
NAR TU2	1.97	na	na	na
Portion of Landing assigned to TU1 ha	0.05	na	na	na
% of GCA as landing +	0.8	5.7	0.0	5.9
% of GCA as landing & roads+	1.4	5.7	0.0	14.6

Silviculture Systems	cc	cc+str	cc	cc
PHSP Designated MSP Treatment	none	none	none	none

	Mt7W	Alki	Slewiskin	Lardeau
Terrain Classification System for B.C. (1980)	SglMvh//Dht	gsFG tl	gsFGva//Mb	Mb
Terrain Complexity	humm	complx	simple	simple
Slope Class/Range	2/0-60	3/7-50	3/29-33	1/0-3
BEC	MSdk	ICHmw2	ICHmw2	ICHmw2
Site Series	01	01/03	01	01
Forest Floor depth cm	10	9	3	8
Forest Floor type	hemimor	hemimor	hemimor	hemimor
0-30cm Soil Texture	SiL-SiCL	SiL	L-SiL	LS-S
Coarse Fragment (%)	25	30	30	10
>30cm Soil Texture	SiCL	L-SiL	L-SL	gS
Coarse Fragment (%)	35-50	35	40	50

Stump Management	ons	ons	50% rem	ons
Stump Hole Area (mean\SEm) m^2	1.0	1.8 /.2	1.9/.2	2.1
Stump Hole Volume (mean\SEm) m^3	na	.6/.1	.5/.1	0.9
no. stump holes measured	1	18	13	1

Leading Soil Disturbance Hazard (LSDH) in PHSP*	C,D=H	C=M	all=M	all=M
Forest Floor Displacement Hazard in PHSP	H	not given	not given	not given
Study Assessed LSDH	C=H;D=VH	C=M-H (Mw=M-H)	E,Mw=M	D=M
Study Assessed Forest Floor Displacement Hazard	VH	H	H	H
Counted MSP Pot. Detrimental Categories**	P,WS,CG	P,WS,CG	P,WS	P
MSP Guideline Pot. Detrimental Max.	6	13	13	13
MSP Guideline Total Displacement Max.	15	25	30	30
Compliance with Armillaria Soil Sensitivity Guidelines	N:FF,D	Y	Y	Y

Slope Classes
1: 0 - 1
2: 6 - 15
3: 16 - 30
4: 31 - 45
5: 46 - 70
6: 70 - 100

Equipment Codes
ls = line skidder
gs = grapple skidder
rts = rubber tired skidder
sc = small cat
ex = excavator
fb = feller - buncher
D4H = high drive small caterpillar

Silviculture System
cc=clear cut
str=single tree retention

Skidding Pattern
rsk=random skidding
dsk=designated skidding

Notes on landings:
a =estimated GCA
b =harvesting incomplete
c =landing shared with immediate TU
d =landing shared with several blocks in area

+ calculated based on the portion of landing attributed to TU1

Leading Soil Disturbance Hazards Types (LSDH):
E=erosion
D=Displacement
Mw=Mass wasting
C=Compaction
FF=Forest Floor

LSDH Ratings:
H=high; M= moderate; L=Low

****MSP Counted Disturbances**
"P"=G,W,VW,LG = deep gouge, wide gouge, very wide scalp, long gouge
WS=wide scalp
C=continuous scalp

Stump Management

ons	on site
rem	removed
onsr	on skid roads

5.0 RESULTS AND DISCUSSION

The following presentation of results and discussion focuses on MSP type disturbance categories, total potentially detrimental disturbance and total soil displacement, and site compliance with the *Armillaria Soil Sensitivity Considerations*. Information on timber harvesting soil disturbance and on roads and landings is summarized in Appendix F and G, respectively. Site specific information on disturbance categories is available through the NFR pedologist.

As outlined in Section 3.0, significant differences between the 1992 and 1993 surveys make direct comparisons difficult. For this reason, the results are discussed separately, with more emphasis placed on the more recent and detailed 1993 results. Specific discussion on soil disturbance categories is restricted to the 1993 detailed surveys.

5.1 MSP and Stump Hole Soil Disturbance Categories

Of the six 1993 MSP disturbance categories, the deep gouge (G) and wide gouge (WG) were most commonly observed. The wide scalp (WS) was less frequently observed and the very wide scalp (VW), continuous scalp (C) and long gouge (LG) rarely or not recorded[17] (Table 6). The deep gouge was always and the wide gouge commonly associated with stump holes. The two additional disturbance categories (G2 and ST) were common and by definition always associated with stump holes.

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[17] A distinction between WG and Wc was not made in the survey. In the majority of cases, wide gouges not associated with a stump hole were associated with heavy or moderate traffic disturbances.

Table 6. MSP type disturbance categories (% of NAR)

	WG	WS	G+G2+ST[1]	LG	VW	C
Wetask	3.8	1.0	19.6	0.0	0.5	0.0
Chatter	1.0	1.8	13.5	0.3	0.5	0.3
Kaslo	2.4	2.9	13.8	1.0	1.2	0.4
E.Kidd	2.2	2.5	6.5	0.4	5.2	0.2
ChrisV	0.2	0.3	5.1	0.1	0.3	0.0
Colepitts	2.1	1.3	9.2	0.2	0.6	0.0
Mt7s	4.2	1.4	13.2	0.5	1.3	0.3
Mt7w	0.4	1.0	10.1	0.0	0.5	0.0
Alki	0.4	0.3	7.4	0.0	0.1	0.0
Slewiskin	1.1	1.2	18.3	0.0	0.2	0.0
Lardeau	0.2	0.6	8.8	0.1	0.0	0.0

[1] all stump holes including those meeting the criteria for other MSP categories

5.1.1 Stump Hole Categories as a Percentage of NAR

Disturbance categories used in 1993 provided a good estimate of the area occupied by stump holes. Soil disturbance directly associated with stump holes varied from 5.1-19.6% of NAR. The percentage of NAR as stump holes decreased in the following general order: stumped > winter PO ≅ summer PO. This is at best a general trend in view of the limited replication within treatment types.

Factors that possibly contribute to within- and between-treatment variability in number and size of stump hole include:

- stand characteristics. The number and to a certain extent the size of stump holes will be related to stand factors such as stand density, tree dbh (Bloomberg and Reynolds 1988; Kozlowski *et al.* 1991; Golob and Silversides 1978; Keays 1971), species composition, and uniformity in tree distribution.
- site (e.g., terrain, terrain complexity, soil texture, site productivity).
- operator experience.
- soil conditions during operations (i.e., whether the soil is dry, wet or frozen).

Replication of these factors in this study was minimal if at all. The influence of these factors on soil disturbance can be evaluated for these sites once additional replication is available through future surveys.

5.1.2 Stump Hole Characteristics

Survey Stump Hole Categories

Disturbance categories G and ST characterized much of the stump hole disturbance on all treatment units (Figure 1). The proportion of stump holes also meeting the wide gouge (WG) criteria varied from less than <1% to 30% (Figure 2). Stumped treatment units had a higher proportion of wide gouges associated with stump holes which may reflect more difficulty in extracting stumps without the added leverage of the tree trunk used in PO logging. Other confounding factors included soil texture, season, soil condition (e.g., moisture).

"Representative" Stump Hole Dimensions

Table 7 summarizes estimates of "representative" mean stump hole (gouge) area, maximum depth, and volume by season and system. Individual treatment unit calculations are given in Appendix H.

Mean stump hole area ranged from 1.0-10.2 m^2. For six of the 11 treatment units, the mean stump hole area exceeded the criteria for the wide gouge (2.6 m^2). Mean maximum stump hole depth was always greater than 30 cm. Estimates of mean stump hole volumes ranged from 0.5-4.3 m^3 [18]. Stump hole area and volume tended to be less for the winter PO treatment units compared with the summer PO and stumped treatment units. The exception was the Christian Valley summer PO treatment unit which had a mean stump hole area and volume comparable to the winter PO treatment units. Reasons for this are not apparent. A report presenting more detailed stump hole areas and volumes for two treatment units is in progress (Redfern 1993).

Deposits in Stump Holes

The majority of stump holes were either empty or filled with woody debris deposits[19] (Figure 3). Typically fewer than 20% of the stump holes contained any mineral deposit. The exception was the one summer stumped treatment unit where 41% of the stump holes were filled with mineral deposits.

On the stumped treatments, mineral deposits tended to be evenly divided between the three depth categories. On the PO treatments, mineral deposits in the stump holes were predominantly less than 15 cm deep.

Table 7. Estimates of mean stump hole area, maximum depth and volume

Treatment	**Season**	**Site**	**Soil Texture (%CF)**	**n**	**Area (m^2)^1**		**Max. Depth (cm)^2**		**Treatment**	
					mean	SEm	mean	SEm	mean	SEm
ST	summer	Wetask	L-SL (25)	9	5.6	1.8	47.1	5.8	2.2	1.0
ST	winter	Chatter	Sil (50)	7	10.2	3.0	51.1	8.6	4.3	1.8
		Kaslo	Sil-LS (40)	13	4.3	1.2	50.2	9.8	2.2	0.8
PO	summer	E.Kidd	L (35)	8	2.4	0.8	57.7	8.4	1.7	0.5
		Christian V.	fSL (25)	12	1.6	0.3	38.5	4.9	0.5	0.1
		Colepitts	SiL-SiCL (10)	13	3.0	0.3	46.4	3.6	1.1	0.2
		Mt.7	SiL (10)	8	3.1	1.0	56.3	5.9	1.4	0.6
PO	winter	Mt.7	SiL-SiCL (25)	1	1.0	na	na	na	na	na
		Alki	SiL (30)	18	1.8	0.2	43.9	3.6	0.6	0.1
		Slewiskin	L-SiL (30)	13	1.9	0.2	39.7	1.7	0.5	0.1
		Lardeau	LS-S (10)	1	2.1	na	60	na	0.9	na

1. Assumed square or rectangle for major axes.
2. Maximum depth generally in centre of stump hole.
3. Assumed a square or rectangular shape; calculated using product of area and 70% of maximum depth.

* definition of a WG: >5 cm deep scalp occupying 80% of 1.8 x 1.8 m or 2.6 m^2.

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[18] 10-12 m^3 of soil fills a regular dump truck. While soil is not removed off-site during stump removal, the truck volume provides a common basis for visually sizing a stump hole, a large portion of which was originally occupied by the stump and large roots.

[19] All depths 1: 0-15 cm; 2: 15-30cm; 3: >30cm.

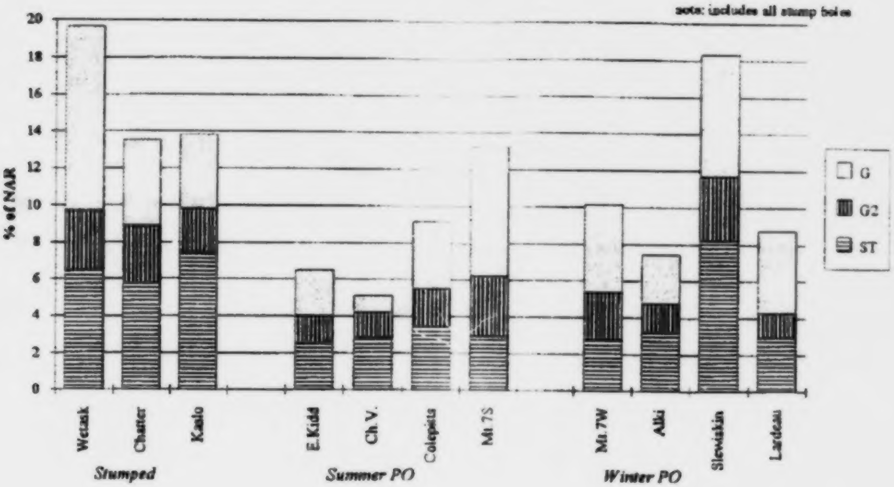

Figure 1 - Partitioning of Stump Holes by Disturbance Category
1993 Surveys

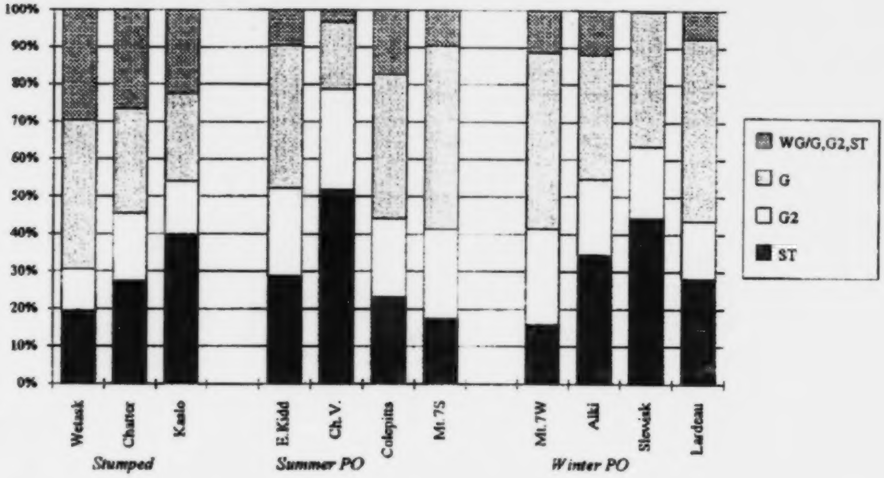

Figure 2 - Percent of Stump Holes Meeting the Wide Gouge Criteria
1993 Surveys

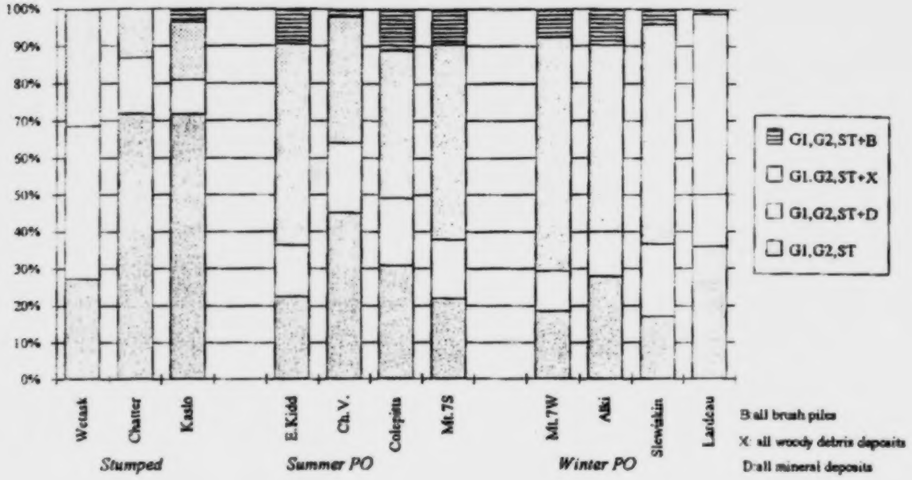

Figure 3 - Percent of Stump Holes (G,G2,ST) With and Without Deposits
1993 Surveys

5.1.3 Future Stump Hole Characterization

The evaluation of soil disturbance created by a new MSP treatment requires site specific, quantitative information on the dimensions and distribution of all disturbance types. This information is needed to:

- define potentially detrimental or excessive soil disturbance
- evaluate the source of different disturbance types post-treatment
- recommend remedial steps to minimize treatment specific disturbances.

Data on stump hole size and distribution from the 1993 surveys are qualitative. The 1993 stump hole categories were chosen with the intent of adopting or modifying where necessary existing MSP disturbance categories. The 1993 results showed that existing MSP soil disturbance categories or modifications of these categories will not adequately characterize disturbance created by stump removal. The deep gouge disturbance category (G) is used to illustrate this point, since this MSP category is most similar to a stump hole.

Mounding, if properly executed, creates a gouge of approximately 0.6 m^2 (i.e., 1.0 m (L) x 0.6 m (W)) and <30 cm deep[1]. If the depth exceeds 30 cm this disturbance is counted as "potentially detrimental." Assuming 800 mounds per hectare, the resultant gouges will occupy 4.8% of NAR. In comparison, the 1993 stump hole areas ranged from 1 m^2 to over 5 m^2 and commonly exceeded 30 cm at maximum depth. Assuming an average stump hole area of 2 m^2, the removal of 800 stumps per hectare will result in 16% of NAR occupied by stump holes. This illustrates that the area criteria for the deep gouge does not characterize the area associated with a stump hole.

Stump holes require a separate disturbance category. The stump hole should be the point object, with qualifying area and depth criteria.

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[1] L. Bedford, Site preparation and planting officer, Silviculture Branch, B.C. Ministry of Forests, Victoria, personal communication.

Initially, the new stump hole disturbance category should be divided into area classes to facilitate data collection on size distribution (Table 8). Type of deposit (e.g., woody debris, mineral soil) and depth of deposit from the soil surface should also be coded for.

Further, detailed information on gouge dimensions should be documented in 1994/95 on a random sample of stump holes within each size class over a range of site and stand characteristics. This information will be used to refine the stump hole area criteria if necessary.

Table 8. Proposed stump hole categories

Class	**Dimensions (m)**	**Equivalent Area m^2**
ST1	> 1.8x1.8	3.2
ST2	1.8x1.8 - 1.0x1.0	1.0 - 3.2
ST3	<1.0x <1.0	<1.0

Fill Qualifier:	
M	plantable mineral soil
W	woody debris & brush

Depth of Fill from Soil Surface	**Depth (cm)**
a	<10
b	10-20
c	21-30
d	>30

5.2 1992 and 1993 Stump Removal Soil Disturbance Surveys

As outlined above, more detailed information on stump hole characteristics is required to evaluate which disturbances are considered potentially detrimental. In the interim, two definitions of total potentially detrimental disturbance are discussed to provide preliminary information on "achievable" disturbance levels. The two definitions bracket a less ("status quo") and more restrictive interpretation of potentially detrimental soil disturbance, but do not encompass the extremes (see Section 3.5).

It is expected that the future definition of potentially detrimental disturbance will lie somewhere between these two. As a cautionary step, given the limited available information, more emphasis is placed in the following on the more restrictive definition of potentially detrimental disturbance.

Total soil displacement is defined according to the *MSP Guidelines* (but including the additional stump categories) since limiting forest floor displacement is a concern for both MSP and stump removal treatments. The total maximum permitted may or may not be adjusted based on future survey results.

5.2.1 Total Potentially Detrimental Disturbance and Total Displacement

The 1992 survey results of total potentially detrimental disturbances and lower confidence limits (LCL (90%)) based on the less and more restrictive definitions are presented in Figures 4 and 5, respectively. Similar information is presented in Figures 7 and 8 for the 1993 survey. Treatment unit specific MSP potentially detrimental soil maxima (BCMF 1993a) are included in the figures for reference. Treatment unit total soil displacement, LCL (90%) and *MSP Guidelines* maxima are presented in Figures 6 and 9, respectively, for 1992 and 1993 surveys.

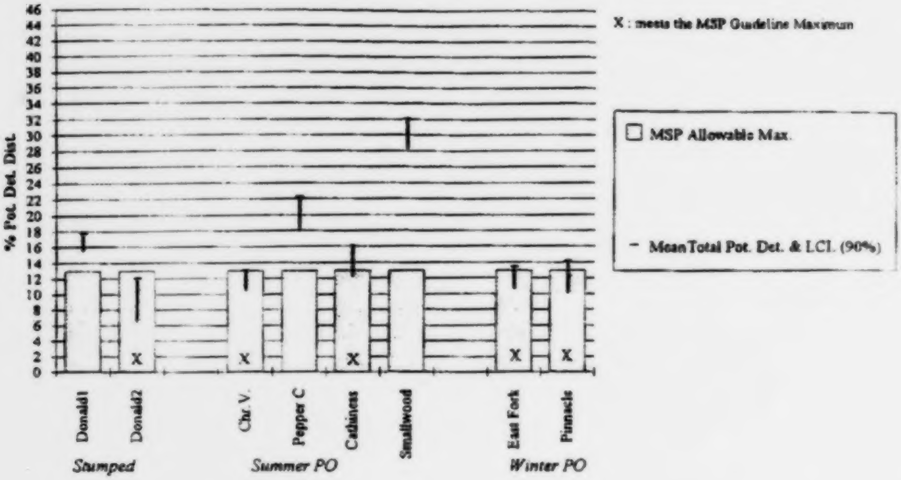

Figure 4 - 1992 Survey Total Potentially Detrimental Disturbance
Less Restrictive Definition

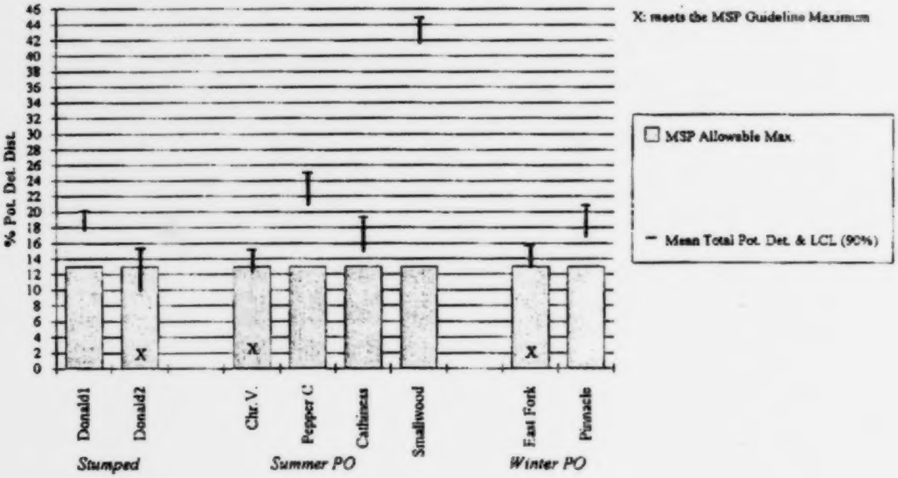

Figure 5 - 1992 Survey Total Potentially Detrimental Disturbance
More Restrictive Definition

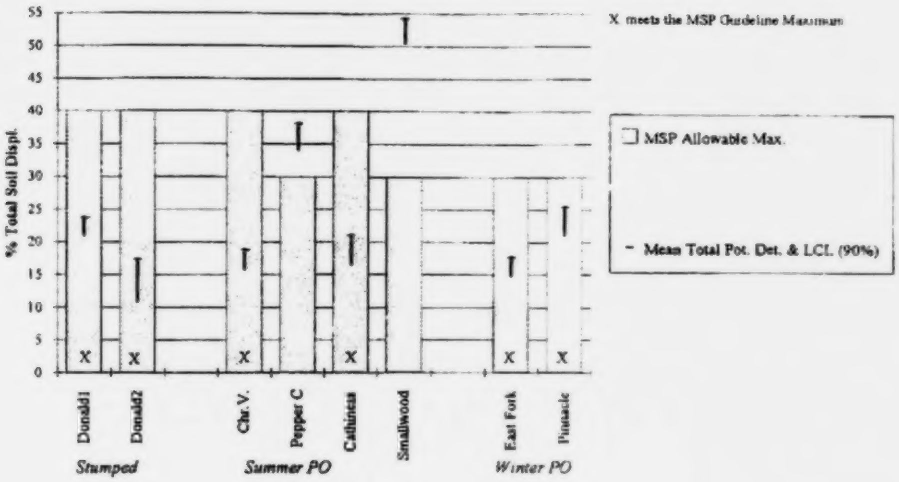

Figure 6 - 1992 Survey Total Soil Displacement

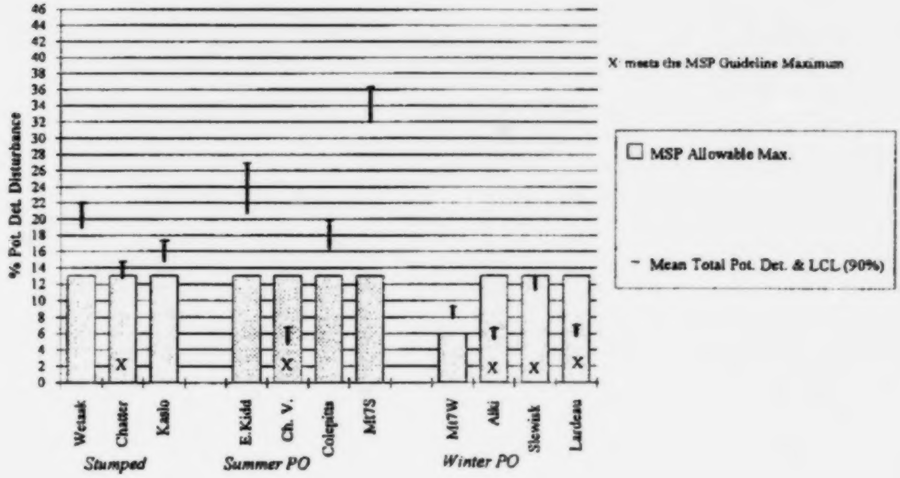

Figure 7 - 1993 Survey Total Potentially Detrimental Disturbance
Less Restrictive Definition

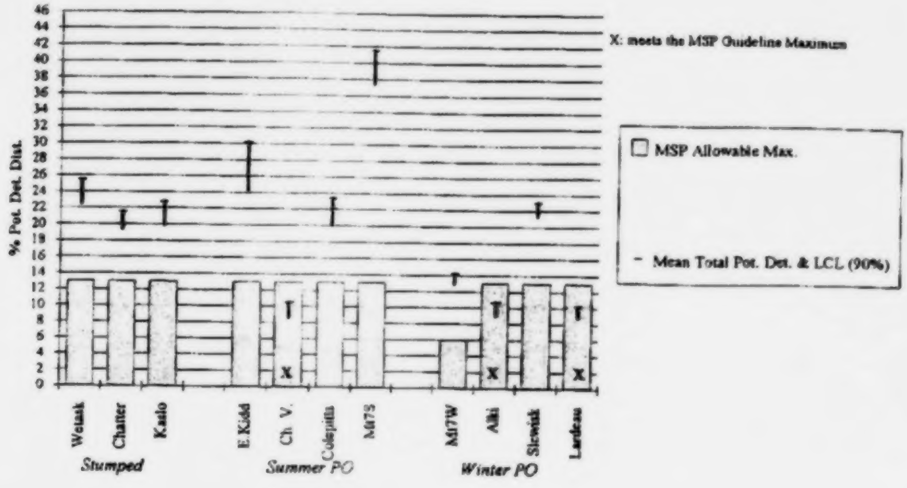

Figure 8 - 1993 Survey Total Potentially Detrimental Disturbance
More Restrictive Definition

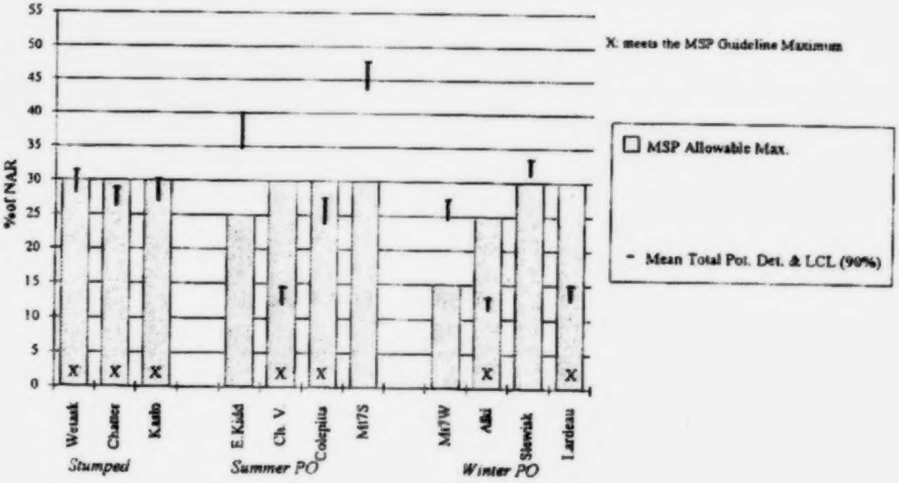

Figure 9 - 1993 Survey Total Soil Displacement

Treatment units meeting the MSP maxima for total potentially detrimental disturbance and total soil displacement are indicated in the figures with an "X." Compliance is based on the lower 90% confidence limit (NFRT 1994)[2]. Table 9 summarizes the number of sites in compliance. More detailed information on total potentially detrimental soil disturbance and total soil displacement by disturbance categories is summarized in Appendix I.

Table 9. Percentage of 1992 and 1993 treatment units meeting the *MSP Guidelines* based on LCL (90%)

	1992		1993	
Season	**Stumped**	**PO**	**Stumped**	**PO**
Less Restrictive Defn.				
Summer	0%	50%	0%	25%
	[0/1]	[2/4]	[0/1]	[1/4]
Winter	100%	100%	50%	75%
	[1/1]	[2/2]	[1/2]	[3/4]
Total	50%	67%	33%	50%
	[1/2]	[4/6]	[1/3]	[4/8]
More Restrictive Defn.				
Summer	0%	25%	0%	25%
	[1/1]	[1/4]	[0/1]	[1/4]
Winter	100%	50%	0%	50%
	[1/1]	[1/2]	[0/2]	[2/4]
Total	50%	33%	0%	38%
	[1/2]	[2/6]	[0/3]	[3/8]
Displacement				
Summer	100%	50%	100%	50%
	[1/1]	[2/4]	[1/1]	[2/4]
Winter	100%	100%	100%	50%
	[1/1]	[2/2]	[2/2]	[2/4]
Total	100%	67%	100%	50%
	[2/2]	[4/6]	[3/3]	[4/8]

[ ] bracketed numbers indicate sample size

1992 Surveys

1. Less Restrictive Definition of Potentially Detrimental Disturbance (Figure 4)

Stumped

Based on the less restrictive (status quo) definition, total potentially detrimental soil disturbance for the winter and summer stumped treatment units was 12.1 and 17.7% of the NAR, respectively. The LCL (90%) of the winter stumped treatment unit met the *MSP Guidelines* maximum for potentially detrimental soil disturbance (Donald2).

PO Logged

Based on the less restrictive disturbance categories, total potentially detrimental disturbance ranged from 13.0 to 32.0% of NAR. The LCL (90%) of four of the six PO treatment units met the total potentially detrimental disturbance *MSP Guidelines* maxima; this included two of the four summer and both winter treatment units. The two summer treatment units not meeting the *MSP Guidelines* maxima (Pepper Cr., Smallwood) were considered either difficult to harvest[3] or subject to post-harvest disturbances. On these two treatment units, non-compacted heavy traffic skid trails (based on 1992 compaction definition) were common and counted as moderate traffic (M). The proportion of the moderate traffic reassigned to the heavy traffic (Hc) category, to bring the 1992 results into line with the 1993 results, may be elevated (see Appendix E). In this case the total potentially detrimental timber harvesting disturbance will be overestimated.

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[2] For a given site, field determination of actual compliance is based on whether the PHSP and logging plans were followed and on the measured level of disturbance. For example, harvesting operations may not adhere to the logging plan but the total level of soil disturbance may be less than the PHSP maximum. This treatment unit would be non-compliant.

2. More Restrictive Definition of Potentially Detrimental Disturbance (Figure 5)

Stumped

Based on the more restrictive definition, total potentially detrimental soil disturbance only marginally increased on the stumped treatment units. For the winter and summer treatment units, total potentially detrimental disturbance was 15.2 and 20.0%, respectively. The winter stumped treatment unit met the *MSP Guidelines* maximum; the summer stumped treatment unit did not.

PO Logged

Based on the more restrictive definition of total potentially detrimental disturbance, only two of the PO treatment units met the *MSP Guidelines* maxima: one summer and one winter treatment unit. Total potentially detrimental disturbance for the remaining four PO treatment units ranged from 19.2 to 44.7% of the NAR. As mentioned above, the harvesting disturbance may be overestimated for Pepper Cr. and Smallwood.

It is noted that Smallwood, which had the highest total potentially detrimental disturbance and was not in compliance with the *Armillaria Soil Sensitivity Considerations*, was harvested with diligence and in compliance with the logging plan (Davis 1993). The excessive disturbance was ascribed to:

- difficult site characteristics, e.g., steep slope pitches, rock outcrops;
- the relative newness of pushover logging; and,
- absence of detailed on-site briefings with equipment operators on the importance of controlling forest floor displacement on sensitive sites.

3. Total Soil Displacement (Figure 6)

With the exception of two summer PO treatment units, all treatment units met the *MSP Guidelines* maxima for total soil displacement. These two summer PO treatment units also had the highest total potentially detrimental disturbance. For the remaining treatment units total soil displacement represented less than 21% of NAR. These 1992 total soil displacement levels underestimate the actual forest floor displacement, since scalping was not recorded at each sample point.

1993 Surveys

1. Less Restrictive Definition of Potentially Detrimental Disturbance (Figure 7)

Stumped

Based on the less restrictive (status quo) definition, total potentially detrimental soil disturbance for the three stumped treatment units ranged from 14.7 to 22% of NAR. The LCL (90%) of only one winter stumped treatment unit (Chatter) met the *MSP Guidelines* maximum for potentially detrimental disturbance.

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[3] The Smallwood TU was considered difficult to harvest as a ground-based operation due to the slopes and irregular terrain. Due to the steep pitches, unplanned "feeder" trails were required.

PO Logged

Based on the less restrictive disturbance categories, the LCL (90%) of four of the eight PO treatment units met the *MSP Guidelines* maximum for potentially detrimental soil disturbance. In total, six of the eight PO treatment units were below 20% total potentially detrimental disturbance based on both the mean and LCL (90%).

2. More Restrictive Definition of Potentially Detrimental Disturbance (Figure 8)

Stumped

With the inclusion of the additional stump hole categories, potentially detrimental soil disturbance ranged from 21.5 to 25.5% of NAR on the stumped treatment units. None met the *MSP Guidelines* maxima for total potentially detrimental disturbance.

PO Logged

Based on the more restrictive definition, total potentially detrimental soil disturbance for the PO treatment units ranged from 10.2 to 41.5% of NAR. Based on the LCLs (90%), three of the eight treatment units met the *MSP Guidelines* maximum: one summer and two winter treatment units. These three treatment units encompass a range of site sensitivities, slopes and slope complexities.

For six of the eight PO treatment units, total potentially detrimental disturbance was less than 24% of NAR. Based on the LCL (90%), total potentially detrimental disturbance was less than or equal to 20% for five of the eight PO treatment units. In general, total potentially detrimental disturbance was greater for the summer than winter PO treatment units.

The total potentially detrimental soil disturbance for two summer PO treatment units (E.Kidd and Mt7s) were noticeably higher than the remaining nine treatment units. Specific reasons for these high numbers are unclear. It has been suggested that for Mt7s an increase in scalping disturbance may have been caused by whole tree skidding on designated trails[4].

Based on the remaining treatment units, it is questionable whether the above two treatment units represent benchmark level operations. They do, however, illustrate the potential sensitivity to summer PO logging of sites with high forest floor displacement hazards. If these two treatment units are set aside, 77% (seven of nine) of the remaining treatment units have total potentially detrimental disturbances of less than 20% of NAR based on the LCL (90%).

The generally lower total potentially detrimental soil disturbance associated with winter compared to summer PO logging is supported by the comparison of the Mt. Seven treatment units. Total potentially detrimental disturbance for the winter treatment unit was less than 25% that of the summer treatment total. PO logging on the Mt. Seven winter treatment unit was undertaken when the soils were frozen.

3. Total Soil Displacement (Figure 9)

Based on the LCL (90%), seven of the 11 treatment units met the *MSP Guidelines* maximum for total soil displacement. All three stumped treatment units were included. An eighth treatment unit had a total soil displacement of less than 30% of NAR (Mt7 w), but exceeded the treatment unit specific sensitivity maximum of 25%.

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[4] For Mt7s the timber sale license (TSL) required designated trails for skidding (20m distances), but did not limit excavator traffic. On both TSLs (winter and summer) the trails were prelocated. D. English (Golden Forest District) suggested that some points tallied may have been areas where the excavator had traveled and non-compacted heavy skid trails may have been paths created by timber being winched to the skidder. The Colepitts treatment unit had similar TSL requirements.

5.2.2 Partitioning of Total Potentially Detrimental Disturbances

The following tables and graphs provide a general overview of the partitioning between major disturbance types: stump hole, non-stump hole MSP, and timber harvesting. Tables 10 and 11 summarize disturbance types as a percentage of each treatment unit's total potentially detrimental disturbance for the 1992 and 1993 surveys, respectively. Based on the more restrictive definition, Figures 10 and 11 present average treatment potentially detrimental disturbance, partitioned into disturbance types (% of NAR), for the 1992 and 1993 surveys, respectively.

1992 Surveys

1. Partitioning as % of Treatment Unit Total Potentially Detrimental Disturbance

Based on the average percentage of treatment total potentially detrimental disturbance, total MSP disturbance (stump hole and non-stump-hole) increased in the following order, irrespective of definition: stumped >winter PO >summer PO treatments. Total timber harvesting disturbances followed the reverse order. For the summer PO treatment units, timber harvesting disturbances in general represented over 50% of the total potentially detrimental disturbance.

The more restrictive definition generally resulted in a 10-15% increase in the proportion of total MSP disturbances compared to the less restrictive definition. Using the more restrictive definition, the proportion of the total MSP disturbance occurring as stump holes ranged from 59-76% of treatment unit total potentially detrimental disturbance.

2. Partitioning as % of NAR (more restrictive definition only)

As a percentage of NAR, the average (SEm) stump hole MSP disturbances were 8.1 (1.5), 8.5 (3.1) and 9.0 (0.9) % for winter PO, summer PO and stumped respectively. The average non-stump-hole MSP disturbances were comparable between the stumped (4.6/1.9) and summer PO logged (5.5/2.5), and slightly less for the winter PO logged (3.0/0.9) (average/SEm) treatments. Noticeable differences in timber harvesting disturbances (excluding skid roads) were apparent. Based on the more restrictive definition of potentially detrimental disturbance, the 1992 average timber harvesting disturbances accounted for 5.0 (0.9), 5.8 (0.2) and 10.2 (0.7) % of NAR for winter PO, summer PO and stumped treatments, respectively. Skid road disturbances were comparable between all treatments.

1993 Surveys

1. Partitioning as % of Treatment Unit Total Potentially Detrimental Disturbance

In general, the proportion of each treatment unit's total potentially detrimental disturbance occurring as MSP disturbance increased as follows, irrespective of the definition: stumped >winter PO>summer PO treatments. Timber harvesting disturbances followed the reverse order. For the summer PO treatment units, timber harvesting potentially detrimental disturbance represented approximately 50% of the total.

Based on the less restrictive definition, total MSP disturbance on the stumped and winter PO treatment units on average represented over 70% of the total potentially detrimental disturbance. For the summer PO treatment units, the mean total MSP disturbance represented less than 45% of the total potentially detrimental disturbance. The proportion of the total MSP disturbance assigned to stump holes varied, but generally represented less than 40% of the treatment unit total potentially detrimental disturbance.

Based on the more restrictive definition, total MSP disturbance on the stumped and winter PO treatments on average represented over 80% of the total potentially detrimental disturbance. Stump holes represented 73% and 90% of the total MSP disturbance for the stumped and winter PO treatments respectively.

For the summer PO treatment units, the average total MSP disturbance represented less than 55% of the total potentially detrimental disturbance. The percentage of the total MSP disturbance occurring as stump holes was particularly varied for the summer PO treatment units, ranging from 38-85%.

2. Partitioning as % of NAR (more restrictive definition only)

The average (SEm) stump hole MSP disturbance accounted for 8.3 (1.8), 10.5 (2.1) and 14.4 (1.4) % of NAR for the summer PO, winter PO and stumped treatments, respectively. Stump hole disturbances on the summer PO treatment units were less than but comparable to those of the winter PO treatment. The slightly higher stump hole disturbances on the stumped treatment units reflected, in part, the larger area of the stump holes associated with this treatment.

The average non-stump-hole MSP disturbances were comparable for the stumped (5.5/2.0) (average/SEm % of NAR) and summer PO (5.7/2.2) and noticeably less for winter PO (1.4/0.5) treatments. Based on field observations it was suggested that some of the non-stump-hole MSP disturbances may have been areas used for swivel drags, winching timber to the skidder or dragging timber to the landing (English, pers. comm., 1994[5]). These activities can create scalped corridors and widen designated trials due to branches dragging on the forest floor. All 1993 treatment units have high or very high forest floor displacement hazards. In the case of stumped treatment units, soil disturbance surveys post-harvest and post-stump removal are required to distinguish source of disturbance.

Noticeable differences in timber harvesting disturbance were also apparent. The average timber harvesting disturbances (excluding skid roads) were 8.1 (1.3), 1.8 (0.4) and 1.7 (0.3) % of NAR for summer PO, winter PO and stumped treatments, respectively. The 1993 average skid road disturbances were noticeably higher (average/SEm % of NAR) on the summer PO (4.3/3.2) compared to the winter PO (0.9/0.5) or stumped (1.9/0.7) treatments. Of the summer PO treatment units, all four had high or very high forest floor displacement hazards and three had high compaction hazards. Both random and designated skidding patterns were represented in these treatment units, but trends in timber harvesting disturbance were not apparent.

It is noted that although total potentially detrimental disturbance was generally highest for the summer PO treatment, on one of the four summer PO treatment units potentially detrimental disturbance was noticeably less. On that treatment unit, timber harvesting and stump hole soil disturbances were less than 5% of NAR. Non-stump-hole soil disturbance was minor. This exception to the general trend emphasizes the need for further information on well-executed operations to evaluate the influence of factors such as slope, equipment complexes, block shape and operator experience on timber harvesting and non-stump hole MSP disturbances.

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[5] D. English, Small Business Prgram, Golden Forest District, Nelson Forest Region

Table 10. Partitioning of 1992 total potentially detrimental disturbance

	Stumped		Summer PO				Winter PO		*Stumped*	*Summer PO*	*Winter PO*
	Don1	*Don2*	*ChrisV*	*Pepper Cr.*	*Caithiness*	*Smallwood*	*East Fork*	*Pinnacle*			
Less Restrictive Defn.[1]: % of Total Pot. Det.									average	average	average
• as Timber Harvesting	20.1	36.2	63.0	64.4	73.3	43.8	51.1	51.9	28.2	61.1	51.5
• as MSP (non stump hole)	37.0	22.4	21.6	19.4	11.8	40.6	16.0	28.4	29.7	23.4	22.2
• as MSP (stump holes)	42.9	41.4	15.4	16.2	14.9	15.6	32.9	20.5	42.2	15.5	26.7
% of MSP as Stump Holes	54	64	42	46	56	28	67	42	59.0	43.0	54.5
More Restrictive Defn.[2]: % of Total Pot. Det.											
• as Timber Harvesting	17.7	28.8	54.4	57.2	61.2	31.4	43.9	35.2	23.3	51.1	39.6
• as MSP (non stump hole)	32.7	17.7	18.7	17.2	9.9	29.0	13.7	18.7	25.2	18.7	16.2
• as MSP (stump holes)	49.6	53.5	26.9	25.6	28.9	39.6	42.4	46.1	51.6	30.3	44.3
% of MSP as Stump Holes	60	75	59	60	74	58	76	71	67.5	62.8	73.5

Table 11. Partitioning of 1993 total potentially detrimental disturbance

	Stumped			Summer PO				Winter PO				*Stumped*	*Winter PO*	*Summer PO*
	Wetask	*Chatter*	*Kaslo*	*E. Kidd*	*Chris.V*	*Colepitts*	*Mt7s*	*Mt7w*	*Alki*	*Slewiskin*	*Lardeau*			
Less Restrictive Defn.[1]: % of Total Pot. Det.												average	average	average
• as Timber Harvesting	13.6	32.0	15.1	49.6	70.2	53.1	58.1	28.6	38.0	28.9	24.1	20.2	57.8	29.9
• as MSP (non stump hole)	53.2	41.6	61.1	48.0	19.4	40.8	35.0	62.7	48.4	14.7	55.9	51.9	35.8	45.4
• as MSP (stump holes)	33.2	26.4	24.8	2.4	10.4	6.1	6.9	8.7	13.6	56.4	20.0	28.1	6.5	24.7
% of MSP as Stump Holes	38	39	29	5	35	13	17	12	22	79	26	35.3	17.5	34.8
More Restrictive Defn.[2]: % of Total Pot. Det.														
• as Timber Harvesting	11.7	21.8	11.5	44.1	45.1	44.9	50.8	18.6	23.7	16.3	16.5	15.0	46.2	18.8
• as MSP (non stump hole)	21.0	16.4	32.9	34.6	8.2	17.8	17.9	12.6	7.6	10.8	3.3	23.4	19.6	8.6
• as MSP (stump holes)	67.3	61.8	55.6	21.3	46.7	37.3	31.3	68.8	68.7	72.9	80.2	61.6	34.2	72.7
% of MSP as Stump Holes	76	79	63	38	85	68	64	85	90	87	96	72.7	63.8	89. 5

[1] only includes deep gouge category [2] includes all three categories for stump holes which are not filled with plantable mineral soil

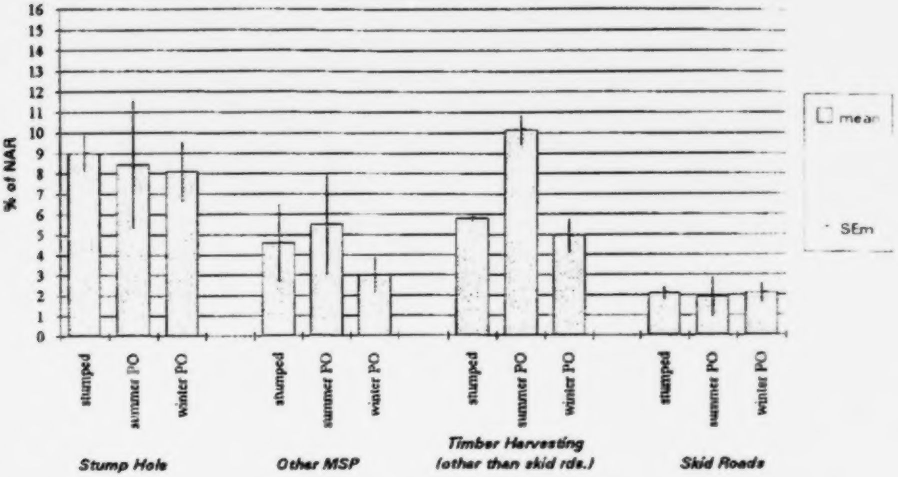

Figure 10 - Partitioning of Total Potentially Detrimental Disturbance
1992 Survey / *More Restrictive Definition*

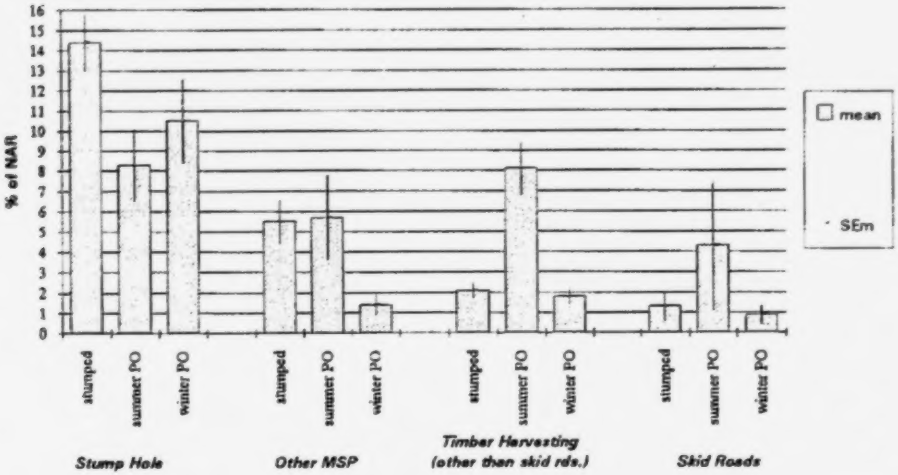

Figure 11 - Partitioning of Total Potentially Detrimental Disturbance
1993 Survey / *More Restrictive Definition*

5.2.3 Future Soil Disturbance Surveys

Soil disturbance created through stump removal will be less easy to control than disturbance created by timber harvesting and MSP because stump hole size and distribution will vary with stand factors (e.g., dbh, height, density, productivity) in addition to other factors which influence soil disturbance (e.g., site characteristics, LSDHs, operator experience). Limiting potentially detrimental disturbance will require documentation and analysis of the site and stand factors contributing to this variation.

Future surveys will need to:

1. replicate site factors for each treatment and season combination;
2. describe soil conditions at the time of winter stump removal to evaluate the effect of frozen soils on stump hole size and soil removal from the stumps (i.e., deposits in stump holes); and,
3. document stand characteristics[6] to evaluate the relationship between dbh and stump hole size and sph and measured stump hole disturbance.

One of the immediate priorities is to test and evaluate the *Armillaria Soil Sensitivity Considerations* over a wide range of site sensitivities. For this reason, preference in 1994/95 should be given to sites adhering to the *Soil Sensitivity Considerations* [7]. If time and funds permit, designated trials should be undertaken on treatment units meeting the *Armillaria Soil Sensitivity Considerations* but with slopes of 30-45% and with high forest floor or displacement hazards.

In 1994/95, PO logging should be given preference over stumping because of its more widespread use in the NFR. All treatments should be well-planned and -executed and adhere to the *Timber Harvesting Soil Disturbance Guidelines* and *Interim MSP Soil Conservation Guidelines* (BCMF 1993a,b).

As a point of reference Table 12 outlines a few of the basic site factors that potentially influence soil disturbance. The number of benchmark PO logged treatment units surveyed in 1993 are listed. Stand information will need to be superimposed on this matrix. Completion of a matrix to this effect is needed to test some of the assumptions underlying the guidelines in the *Soil Sensitivity Considerations* appendix. This information is also necessary to develop site sensitivity based soil conservation guidelines for stump removal treatments.

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[6] D. Norris, Forest Pathologist, NFR, has suggested using stand and stock compilations from cruising for information on sph, average dbh by species and basal area. Provided the treatment unit and block areas are the same, an "adjustment" factor based on species basal area can perhaps be used to provide a gross estimate of stump hole size. Norris suggested an adjustment factor of nine or three times the average basal area (e.g., average dbh=12 cm; 3 x's dbh = 36 cm; basal area for a 36 cm dbh tree = $0.1 m^2$ x 600 sph = $61m^2$). This approach should be investigated.

[7] In 1994/95, the soil disturbance survey method should be simplified from that used in 1993. Only the most limiting disturbance at each point should be recorded. All disturbance categories, however, should be classified as to scalping in addition to compaction. This will permit a more accurate estimate of total soil displacement. Stump holes should be classified as per section 5.1.

Table 12. Matrix of completed surveys and major site factors assumed to influence disturbance created by stump removal treatments

Season		S	S	S	S	W	W	W	W	W	W	W	W
Slope		<30	<30	30-45	30-45	<30	<30	<30	<30	30-45	30-45	30-45	30-45
Soil Matrix[3]		fine med	coarse	fine med	coarse	fine med	fine med	coarse	coarse	fine med	fine med	coarse	coarse
Soil Condition						not frozen	frozen	not frozen	frozen	not frozen	frozen	not frozen	frozen
Displ+FF Displ	H+H[1]	2					1						
Displ+FF Displ	H+(L-M)												
Displ+FF Displ	(L+M)+H	1		1					1				
Displ+FF Displ	(L,M)+ (L,M,(H)[2])						2		1				

[1] many of the FF displacements are VH
[2] H <19 points
[3] as per SSIWG et al. 1993
[4] all soils were assumed frozen

☐ Treatment units meeting the *Armillaria Soil Sensitivity Considerations*

5.3 Compliance with *Armillaria Soil Sensitivity Considerations*

5.3.1 1992 and 1993 Stump Removal Surveys

The document *Interim Guidelines for Armillaria Management in the Nelson Forest Region* which includes the *Soil Sensitivity Considerations* appendix was circulated early in 1992, even though it was not finalized until 1993. Of the nine treatment units surveyed in 1992, seven complied with *Armillaria Soil Sensitivity Considerations*. Treatment units not in compliance in 1992 included two of four summer PO treatment units and both winter PO treatment units. Of these four treatment units, one met the *MSP Guidelines* based on the LCL (90%).

Of the 11 treatment units surveyed in 1993, four complied with the *Armillaria Soil Sensitivity Considerations* one summer stumped and three winter PO treatment units. Two of the three PO treatment units met the *MSP Guidelines* maxima for total potentially detrimental disturbance (more restrictive definition). The stumped treatment unit did not meet the *MSP Guidelines* maxima.

In total, fewer than 50% of the 19 treatment units surveyed complied with the *Armillaria Soil Sensitivity Considerations*. Forest floor displacement was a common reason for non-compliance, although in 1993, three treatment units were also non-compliant in reference to either the displacement or erosion hazards.

A correlation between total potentially detrimental soil disturbance and compliance with the *Armillaria Soil Sensitivity Considerations* was not evident. Further review of factors currently included and other influencing factors not yet included is needed.

5.3.2 Future Armillaria Soil Sensitivity Considerations

As outlined above, further information is needed to evaluate and revise the above guidelines. Future revisions should include the addition of stand characteristics identified as influencing stump hole disturbances (e.g., age class, species, stems per hectare). In the interim the following comments are made regarding the Mass Wasting and Forest Floor Displacement Hazards.

1. Mass Wasting Hazard

At present, stump removal is permitted on sites with a high (H <31 points) mass wasting hazard. This includes sites identified in the ***MSP Guidelines*** as sensitive to soil disturbance (maximum potentially detrimental disturbance of 6%). Consideration should be given to limiting operational use of stump removal treatments in 1994/95 to sites with L and M mass wasting hazards for the following three reasons:

- soil disturbance concerns of MSP and stump removal are similar;
- information on soil disturbance created by stump removal is limited; and,
- based on the 1993 results a maximum potentially detrimental soil disturbance of 6% will be difficult to achieve with stump removal.

This revision can be reassessed in 1995 based on the 1994/95 surveys.

2. Forest Floor Displacement Hazard

The 1993 survey results suggest that forest floor displacement resulting from stump removal is comparable to what is expected from other MSP treatments. Whether or not the forest floor hazard is too stringent will need to be evaluated in the future based on:

- total displacement measurements on a range of sites following stump removal;
- a review of the relative roles of stumps and forest floor as sources of site organic matter and nutrients; and,
- management options for stumps.

6.0 OVERVIEW

Stump Hole Soil Disturbance

Stump removal creates stump holes, non-stump-hole MSP disturbances (in particular wide gouges and wide scalps) and timber harvesting disturbances. Future soil disturbance surveys will need to quantify all three disturbance types.

The disturbance categories used in 1993 (G, G2, ST) to quantify stump holes provided a good estimate of the area (% of NAR) occupied by stump holes but offer limited information on the distribution of stump hole sizes. The percentage of NAR occupied by stump holes varied considerably between treatment units, ranging from 5.1-19.6% of NAR. In general, stumping resulted in a greater percentage of NAR occupied by stump holes compared to PO logging; this reflects, in part, the larger area of stump holes associated with stumping.

Together, preliminary information on the dimensions of "representative" stump holes and on combinations of disturbance categories (e.g., WG/ST) demonstrated that stump hole areas were comparable to or exceeded those of timber harvesting and MSP disturbances considered potentially detrimental because of compaction (i.e., T,I,H) and/or soil displacement (i.e., WG). Stump hole areas ranged from less than 1 m^2 to greater than 3 m^2 and generally exceeded 30 cm at maximum depth.

Most of the stump holes were not filled with plantable mineral deposits (<20%). Since a large portion of the stump hole is originally occupied by the stump itself, it is unlikely that many stump holes will be filled with mineral soil.

Existing MSP disturbance categories poorly characterize stump holes. A separate soil disturbance category is therefore required to quantify and characterize stump hole disturbance.

Total Potentially Detrimental Disturbance

In the absence of criteria defining which stump hole characteristics are considered potentially detrimental, two definitions bracket a less and more restrictive interpretation of potentially detrimental soil disturbance. It is expected that the future definition of potentially detrimental disturbance will lie somewhere between these two. More emphasis is placed on the more restrictive definition of total potentially detrimental disturbance as a cautionary step, given the limited available information. More emphasis is also placed on the more detailed 1993 survey results. General trends in total potentially detrimental disturbance and total soil displacement are summarized in Table 13.

Based on the more restrictive definition, total potentially detrimental soil disturbance associated with stump removal treatments in 1993 was highly variable, ranging from low (<10% of NAR) to very high (41% of NAR) levels. In general, total potentially detrimental disturbance decreased between treatments as follows: summer PO ≅ stumped > winter PO.

Based on the more restrictive definition, three of 11 1993 treatment units met the *MSP Guidelines* maxima using the LCL (90%): two winter and one summer PO. None of the stump removal treatments met a total potentially detrimental disturbance of 6% of NAR; some met a total potentially detrimental disturbance of 13% of NAR. An upper total potentially detrimental limit of 20% of NAR was met by seven of 11 treatment units (LCL 90%). Based on the more restrictive definition, three of 11 1993 treatment units met the *MSP Guidelines* maximum of 13%: one summer PO and two winter PO (mean value and LCL (90%)). Five of eight PO (63%) and two of three stumped (67%) treatment units met a total potentially detrimental upper limit of 20% of NAR (LCL (90%)).

The general ranking of total potentially detrimental disturbance between treatments reflected the relative abundance of MSP (stump hole and non-stump-hole MSP) and timber harvesting disturbances. Compared to the 1993 winter PO treatment units, non-stump-hole MSP disturbances are common to both summer PO and stumped treatment units and timber harvesting disturbances are common to summer PO treatment units. Stump hole disturbances are comparable between summer and winter PO (averages: 8.3% and 10.5% of NAR) and slightly higher for stumped (average: 14.4% of NAR) treatments.

The above general patterns of disturbance between treatments emphasize two important points:

1. stump holes are a given potentially detrimental soil disturbance, which will represent in the range of 4% to 10% of the NAR, or more. The actual percentages will depend on site, stand and operational factors. It will also depend upon future criteria used to define which stump hole characteristics are detrimental.
2. pre-harvest planning to limit timber harvesting and non-stump-hole MSP disturbances on summer operations, in particular, is necessary if future soil conservation guidelines are to be met.

Total Soil Displacement

All three treatments met a total soil displacement of 30% of NAR, except those with noticeably high total potentially detrimental disturbance. Very few treatment units will be able to meet a total displacement of 15% of NAR.

Future Information Needs (on well-planned and -executed treatments)

Given the number of factors (e.g., season, treatment, site, equipment, stand) which can influence the amount and type of soil disturbance created by stump removal, it is important that a concerted effort is made over the next two years to undertake soil disturbance surveys over a range of site, soil and stand characteristics. This information is needed to:

- characterize stump hole size and distribution;
- define potentially detrimental disturbance specific to stump holes[8];
- document operationally "achievable" total potentially detrimental disturbance over the range of influencing factors; and,
- review efficacy of site sensitivity factors included in the *Armillaria Soil Sensitivity Considerations*.

The above will provide the needed background on soil disturbance to develop soil conservation guidelines specific to stump removal. The definition of potentially detrimental disturbance will reflect trade-offs between soil productivity losses and increased tree growth. Current information on these trade-offs is very limited and, over the longer term, research will need to be undertaken to directly quantify treatment effects over a range of site conditions. In general, it will be expected that soil disturbance guideline maxima will over time merge with those for other MSP, unless the benefits of stump removal can be shown to exceed those of other MSP treatments. The principles of soil conservation apply to all harvesting operations.

Other treatment impacts on the soil (e.g., organic matter losses) and other resources (e.g., habitat) will need to be addressed if not directly in the stump removal soil conservation guidelines then as special recommendations (e.g., CWD retention).

Until further information on soil disturbance associated with stump removal is available, PO logging should be favoured over stumping, and winter PO logging over summer PO logging on sensitive sites. Stump removal treatments should be restricted to treatment units meeting the *Armillaria Soil Constraints*, except for sites with a high mass wasting ranking. Further operational use of stumping or PO logging must include pre-harvest planning in order to minimize timber harvesting and MSP type disturbances during harvest and to rehabilitate skidding disturbance post harvest. These steps will serve to limit soil degradation until further information is available.

Over time, lower levels of potentially detrimental soil disturbance can be expected in response to increased operator experience, operator training initiatives and detailed on-site briefings on specific site sensitivities.

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[8] The definition of potentially detrimental disturbance will be based on the MSP literature for comparable disturbance types, where available, and on first principles. Research studies should be initiated to monitor tree growth on stumping related disturbances.

Table 13. Trends in total potentially detrimental disturbance and total soil displacement based on more restrictive definition

1992 Surveys	*1993 Surveys*
• total potentially detrimental disturbance decreased in the following order: summer PO > stumped > winter PO;	• total potentially detrimental disturbance decreased in the following order: summer PO ≅ stumped > winter PO;
• for summer PO treatments timber harvesting disturbances represented over 55% and for stumped and winter PO treatments MSP disturbances represented over 70% of total potentially detrimental disturbances;	• for summer PO treatments timber harvesting disturbances represented over 50% and for stumped and winter PO treatments MSP disturbances represented over 70% of total potentially detrimental disturbances;
• total potentially detrimental disturbance exceeded 6% NAR on all treatment units • 3 of 8 treatment units met a total potentially detrimental maximum of 13% NAR: 1 stumped, 1 summer PO and 1 winter PO (based on LCL (90%)); • 6 of 8 (75%) treatment units met a total potentially detrimental maximum of 20% (based on LCL (90%));	• total potentially detrimental disturbance exceeded 6% NAR on all treatment units • 3 of 11 treatment units met a maximum potentially detrimental disturbance of 13% NAR: 1 summer PO and 2 winter PO (based on LCL (90%) and mean values) • 5 of 8 PO (63%) and 2 of 3 stumped (67%) treatment units met a total potentially detrimental upper limit of 20% NAR (based on the LCL (90%));
• 6 of 8 (75%) treatment units met a maximum total soil displacement of 25% (based on LCL (90%) and mean values); • only 2 of 8 (25%) treatment units had a maximum total soil displacement of 15% (LCL 90%) or less.	• 8 of 11 (73%) treatment units met a maximum total soil displacement of 30% (based on the LCL (90%)). • 5 (45%) and 3(27%) of 11 treatment units, respectively, had a maximum total soil displacement of 25% and 15% (LCL 90%) or less.

7.0 RECOMMENDATIONS

It is recommended that

1. The implementation of stump removal be phased in as an operational tool to allow time for additional surveys, evaluation and training of operators and soil disturbance surveyors.

2. A formalized Regional soil disturbance survey program be established to coordinate and summarize soil disturbance monitoring on:
    - a minimum of 20-30 PO logged and 5-10 stumped operational benchmark treatment units in 1994/95, encompassing the range of site and soil factors specified in *Armillaria Soil Sensitivity Considerations*.
    - designated operational trials on treatment units with slopes 30-45% and high forest floor and erosion site sensitivity hazards; and,
    - designated operational trials to evaluate options available for rehabilitating stump holes, e.g., spot filling or re-contouring on low sensitivity treatment units (e.g., L forest floor and displacement hazard ratings).

3. Detailed information on site, stand, harvesting operations and soil conditions at time of harvest be documented for each treatment unit and analyzed in the context of measured soil disturbance.

4. A soil disturbance category be created specific to stump holes, with size variants. Systematic documentation of stump hole dimensions by size variant is to be undertaken in the 1994/1995 surveys.

5. The following rules be followed for stump removal operations (non-designated trials) over the next two years:
    - strict compliance with *Armillaria Soil Sensitivity Considerations*, with the one exception being no treatment on sites with an H mass wasting hazard;
    - preference given to winter over summer PO logging on sensitive sites;
    - preference given to PO logging unless there are specific concerns (e.g., operator safety) which would dictate the use of stumping;
    - restricted movement of stumps on site to reduce soil displacement;
    - pre-work conferences to discuss site sensitivities with operators; and,
    - routine reconnaissance surveys during operations to identify any potential problems early on.

6. For operational treatment units designated for stump removal in 1994/95, consider approving PHSP total potentially detrimental disturbances of up to 20% during harvesting, with the requirement for planned rehabilitation of skid roads post-harvest. The PHSP post-harvest maximum should be the 20% minus anticipated gains from rehabilitation as shown on the logging plan, with the objective of reducing the total potentially detrimental disturbance as close to 13% of NAR as possible. The maximum potentially detrimental disturbance permitted during harvesting in 1994/95 should be reviewed prior to the 1995/96 field season based on the results of the additional surveys. A maximum of 30 or 40% total soil displacement should be used in 1994/95 depending upon the leading soil disturbance hazard, as outlined in the *MSP Guidelines*.

    On designated trials (i.e., treatment units which do not meet *Armillaria Soil Sensitivity Considerations*), the maximum allowable potentially detrimental soil disturbance be approved by the Regional Soil Scientist on a site by site basis.

7. The following items be reviewed based on the regional 1994 and 1995 soil disturbance surveys:
    - disturbance categories used to characterize stump removal disturbance;
    - dimensions and categories considered "potentially detrimental" or excessive;
    - potential "trade-offs" of stump removal in terms of organic matter, nutrient and habitat losses, by biogeoclimatic subzone and site series;
    - site sensitivity rules in *Armillaria Soil Constraint Guidelines*; and,
    - options to lower the PHSP soil disturbance maximum total potentially detrimental disturbance.

8. Training be developed specifically for machine operators carrying out PO logging and/or stumping, such as is available for MSP.

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APPENDIX A - NFR Stumped and Pushover Logged Blocks (update to summer 1993)

	Block		Location	Licencee/ SBEFP	Year	Season	Method	Equipment	Harv. Pattern	Stump Manage.	Area	Com.	FFD	Disp.	Eros.	MW	Texture	Slopes	No. of Species	Comments
GD	TSL A34326		Donald H.	SBEFP	91	f	ST	Hitachi270 buck+thumb; ls	DSK?	invert.hole	8.5	H	H	H	H	H	sil 20	2-30		
GD	TSL A34326		Donald H.	SBEFP	91	f	ST	"	DSK?	invert.hole	1.5									
GD	TSL A27283	OP#67	Chatter Cr	SBEFP	90	s-f					6.4		no PHSP						3	clean skid all >20 cm DSH
GD	TSL A32775	OP#89/TU1	Chatter Cr	SBEFP	92	f	ST?	ex? ls	DSK	remove?	4.4	vH	H	H	H	H	sil-sicl	5-35	3	clean skid all >20 cm DSH
GD	TSL A34347		Mt. Seven	SBEFP	93	w(.7m)	PO	Yvariti200;TJ450; CK666; ls	DSK	<35cm buck on site	5.9	H	H	H	M	M	sil	0-65	3	conv. on >33%; clean skid >15 cm DSH;PO(all stems)
GD	TSL A34348		Mt. Seven	SBEFP	93	s	PO	backhoe ex	DSK	?	11.4	H	H	H	M	M	sil 5	5-55	2	conv. on >33%; clean skid >15 cm DSH;PO(all stems)
GD	TSL A34309		Colepitts	SBEFP	93	s	PO	as Mt. Seven? ls	DSK	?	6.3	vH	vH	M	M	M	sicl 30	5-10		
GD	TSL A34310		L. Colepitts	SBEFP	93	w(.7m)	PO	as Mt. Seven? ls	"DSK"	<16" buck on site	7.9	vH	H	H	M	M	sicl 10	5-12	3-4	frozen gr.; soil layer in areas;
GD	TSL A3403		U.Colepitts	SBEFP	93	s	PO(all)	backhoe ex?	DSK?	?	5/8	H	H	H	M	M	sil/sl 10	10-20		PO on <30%; clean skid all >15 cm DSH;
GD			Bluewater 31k	Evans																
GD	FL A17645	CP261 Bk4	L. Foster Cr	EvansFP	93	w	PO(all?)	Cat ? 220 ls	"DSK"	buck on site (all)	9.9	H	x	M	M	M	sil 15	20-35		3 m knockdown; cc to close utilization stand.;
GD	FL A17645	CP261 Bk3	L. Foster Cr	EvansFP	93	?	PO(all?)	Hitachi 200 ex ls	"DSK"	buck on site (all)	19.1	H	x	M	M	M	sil 25	15-35		3 m knockdown; cc to close utilization stand.
GD	FL A17645	CP261 Bk2	L. Foster Cr	EvansFP	93	?	PO(all?)	Hitachi 200 ex ls	"DSK"	buck on site (all)	34.8	H	x	M	M	M	sil 20	15-45		3 m knockdown; cc to close utilization stand.;slope constraints?
GD	FL A17645	CP257 Bk10	Bush R.(Unit3?)	EvansFP	93.?	w?	PO?	Hitachi 200 ex ls	"DSK"	buck on site (all)	21	H	x	H	M	M	sil-sicl 50	0-35		
GD	FL A17645	CP257 Bk9	Bush R (Unit2)	EvansFP	93	w?	PO	ex ls	"DSK"	buck on site (all)	2.3	H	x	M	L	M	sicl 60	5		
GD		CP261 Bk1	Sue Fire/QuartzCr	?	92	?	PU		Spacing		16									
INV	FL A18979	CP Bk37/11	Pinnacle Cr	SFP(Rad.)	91		PO	D6 HTrack,Komatsu (Cat225) ls	DSK	buck @ landing	38.2	M	x	H	M	M	sil 10	0-40		
INV	FL A18979	CP Bk34-6	Westside Rd	SFP(Rad.)	93	s	PO	Komatsu (Cat225); ls	DSK	buck on site(?)	5.7						sil 10	5-35		large existing landing;
INV	FL A18978	CP113 OP72	Mud Cr	CFI(CF)	93	w	PO	Hitachi200;rub. tire skid. ls	RSK/DSK	buck on site(merch)	4	H		M	L	L	sil 30	0-20		ground frozen;mod. branch breakage
INV	FL A18978	CP113 OP72	Mud Cr	CFI(CF)	93	w	PU	Treemax ls	RSK/DSK	buck on site(merch)										
INV	FL A18978	CP26 Bk907	Driftwood	CFI	93	s/f	PO	JohnDeer hoe ls	RSK/DSK	?		H	VH	M	M	M	sil	5-25		
INV	TSL A18982	CP9	Toby Cr	SBEFP	92	s	ST	ex												
INV	TSL A36730		Premier Ridge	SBFEP	93	f	PO	ex	DSK		19	H	M	H	M	M	sil 25	10-30		wildlife-N/S strip harvesting (8ha)
INV	TSL A43116	Bk1	Nine Mile Cr	SBFEP	92	f	PO	ex	DSK		25	M	H	H	L	M	sl 70	0-25		
INV	TSL A43072		Beards Cr	SBFEP	92/3	w,s	PO	ex	RSK	buck on site	25	M	H+	M	M	M+	sil/sl 35	15-30		2 units

	Block		Location	Licencee/ SBEFP	Year	Season	Method	Equipment	Harv. Pattern	Stump Manage.	Area	Com.	FFD	Disp.	Eros.	MW	Texture	Slopes	No. of Species	Comments
CBK			Ft Steele																	
CBK	TSL A38115		Caithness Cr	SBFEP	91		PO	ex?		buck @ landing		H	x	L	L	L	sicl 20	<15		narrow/soil change
CBK	TSL A42341	Bk1	Marysville	SBFEP	92	w	PO	D3	DSK	buck @ landing	4.2	H	H	M	M	L	sil	5		4x4 tracks throughout
CBK			Marysville	Cominco	92				DSK	buck @ landing										area windrowed
CBK	TSL A34244	Unit2	Peavine Cr	SBFEP	93?		PO	bh?	DSK	buck @ landing	7.8	H	M	M	M	M	sil 20	2-40		
CBK	FL A19040	CP306 OP#197	Alki Cr	CFI	93?						7.3	M	x	M	M	M		x		
CBK	FL A19040	CP306 OP#196	Alki Cr	CFI	93?	w	PO?				8.6	M	x	M	M	M		x		
CBK	FL A19040	CP184 Bk1	Lladner Cr	CFI	93	s	PO	ex?			17.6	H	M	L	M	M		20		
CBK	FL A19040	CP184 Bk3A&B	Lladner Cr	CFI	93	s	PO	ex?			13/23	vH	M	L	M	M		15		
B	FLA18969	CP161	Christian Valley	P&T	94	s	PO													
B			Knappen Cr		90		PO	ex?												Too old to survey
B			Pheonix																	Too old to survey
B			Stewart Cr		90		PO	ex?												Too old to survey
B	TFL8	CP3C TU2	E.Bound.	P&T	91	w	PO	ex?			9	H	H	M	M	M	fs-ls	12-28		blow down area; smaller portion of larger area
B	TFL8	CP3C TU3	E.Bound. Pepper Cr	P&T	91	w	PO	ex?			4	M	H	M	M	M	sl-ls	15-30		
B	TFL8	CPA Bk5	West Fork	P&T	91	w	?				20.4	M	x	M	M	M	sl	5-40		
B	FL A18969	CP123 TU2	Christian V	P&T	92		ST	D8 cat			5	H	M	L	L	L	x	<10		5 ha in 16 ha TU
B	FL A18970	CP18 Bk3	U. Rock Cr	P&T	90		?	cat?									ls-s 40	50		
B	FL A18969	CP92 TU2	Damfino-Kettle Confl.	P&T	93?		PO	ex?			14	M	L	L	L		sl-ls	18		
B	FLA18968	CP162	Burrel Cr.	P&T	93	s	PO	modified feller buncher												
B	TFL8	CP81B	Boundary Cr	P&T	95	s	PO	modified feller buncher												
KL	LA36647		Pilot Pt	SBFEP	91?		PO	ex		buck on site	35.9	L		M	M	M	sl	30		small cc's
KL	TSLA36673	BkE	Smallwood 1	SBFEP	92	f	PO	JD790LChoe;KMC 180;JD648D gr.sk.	DSK	buck @ landing	5	L	H	M-H	M	M	sl-l 30	<15-50	3+	
KL	TSL A42110		Smallwood 2	SBFEP	93?		PO	ex		buck @ landing	14	M-H					sil	20		
KL	TSLA36666		E.Kidd	SBFEP	93?	M	PO	ex		buck @ landing	13.5	M					sil	15		4 small blks
KL	FLA20212	CP17TU2	Shorty Cr/Kingsgate	CFI	91?		PO	JD740 Bhoe; line sk. equip.?		buck @ landing	25	L	M	M	L	L		flat		surveyed by CFI
KL	FL3 0176	CP20 Bk2	Mid Lake Cr/Lardeau	SFP	92?		PO?/ST?	Cat225 grapple skidder		buck @ landing	8	M	H	L	M	M	l	10-30		
KL	TSL A36675		Kaslo R	SBFEP	92/93	ST	ex			on site	11.5	M	M	M	M	M	sil	30		
KL	TSL A36660		Kaslo R	SBFEP			ST	ex		on site	17	M	M	M	M	M	sl	20-40		
KL			Smallwood Cr	SBFEP	93?			ex.? - PHSP not finalized												
KL	TSL A30172		Conners Cr	Kalesnikoff	93?		ST	backhoe		buck on site	16.1	M	M	M	M	M	sil	25		water shed/visual restraints
KL	TSLA36672		Mirror Lake	SBFEP		92/93	PO	ex		buck @ landing	11.7	M	M	M	M	M	sl	25		3 small blocks
KL	TSLA36607		Smallwood	SBFEP		92/93	ST	ex		on site	13.6	M	M	M	M	M	sil	15		
KL	FLA30176	CP36Blk3	Lardeau Hwy	SFP	92/93	f/w	PO	ex/gs		buck @ landing	3.1	M	L	L	L	L	sl	flat		
KL	FLA30177	CP36Blk5	Lardeau Hwy	SFP	92/94	f/w	PO	ex/gs		buck @ landing	6.8	M	L	L	L	L	sil	flat		
KL	FLA30178	CP36Blk6	Lardeau Hwy	SFP	92/95	f/w	PO	ex/gs		buck @ landing	7.2	M	L	L	L	L	sil	10		

	Block		Location	Licencee/ SBEFP	Year	Season	Method	Equipment	Harv. Pattern	Stump Manage.	Area	Com.	FFD	Disp.	Eros.	MW	Texture	Slopes	No. of Species	Comments
AR	A15093		Erie Lk	SBEP	84		handfell			buck @ landing	22							0-45		to be rehab. by removing stumps (planned '93)
AR	A20195		Burton	Bell Pole	91		ST													
AR	A38244		Burton	SBFEP	93	s	PO	ex?			6.6							20		to be sold (planned '93)
AR	A20192	CP110 1B	Slewiskin	SFP	93	w	PO	225 ex		buck @ landing	5	M		M	M		sl	20-45	6	birch skidded (clean skid)
AR	A20192	CP110 2B	Slewiskin	SFP	93	w	PO	225 ex		buck @ landing	5.1	M		L-M	L		sl 35/70	15-45	6	not clean skid
REV	82K51	6	Lime Kiln Rd	SBFEP	90	s	ST	Feller Buncher PC300/gs		on site	16	L	H	M	M	L	sl-ls	10-25	7	stumps left outside hole
REV	82L90	48	Bell Rd.	SBFEP	92	f	ST	Hitachi 220 BH		on site	2	L	H	H	M	M	sl	15-30	7	stumps turned upside down in hole
REV	82M68	23	French Cr.	SBFEP	92	f	ST	Hitachi 220 BH		on site	1	M	H	M	H	M	l-sil	30-40	5	
REV			Wetask	SBFEP	93	f	ST	?		on site	19.6	M	H	L	M	L	sl	flat	7	

Seasons

w	winter
f	fall
s	summer
sp	spring

Method

ST	Stumped
PO	Pushover logged
PU	Popup

Harvest Pattern

DSK	Designated Skidding
RSK	Random Skidding

Equipment Codes

ls = line skidder
gs = grapple skidder
rts = rubber tired skidder
sc = small cat
ex = excavator

Silviculture System

cc=clear cut
str=single tree retention

Leading Soil Disturbance Hazards Types:

Eros	Erosion
Disp	Displacement
Mw	Mass wasting
Com	Compaction
FFD	Forest Floor Displacement

Ratings:

H=high; M= moderate; L=Low

APPENDIX B - Ministry of Forests Guidelines

APPENDIX III

Soil Sensitivity Considerations

The following provides guidelines for site conditions where stumping or pushover or pop-up logging should not be considered at this time. These guidelines should be used in conjunction with the five (5) soil sensitivity keys (Curran et al 1990): compaction, displacement, surface erosion, mass wasting and forest floor displacement (FS711, A&B). As further research and field data is collected these guidelines will be subject to review and change.

Stump management is currently under study with the objective of developing guidelines for their disposal or retention on site. In the interim, where possible, stumps should be retained in the:

- PP and IDF subzones - on all sites
- MS, ESSF (dk,dc1) and ICH (xw, dw, mk1) subzones - on mesic and drier sites.

Stumps should not be interpreted as coarse woody debris.

Harvest planning and execution need to be undertaken in a manner to ensure current MSP and harvest disturbance guidelines are met.

Stumping is a high risk activity from the soil disturbance point of view and therefore must always be accompanied by a soil disturbance survey.

Crawler tractors are not to be used to remove stumps in a stumping operation.

TABLE A. Soil sensitivity guidelines

Criteria	Pushover	Post-Harvest St
* Avoid slopes	>30%[10]	>20%[10]
* Avoid all clayey soils[12]	X	X
* Avoid soils <60 cm deep	X	X
* Avoid soils with carbonates <30 cm deep[13]	X	X
* Avoid unfavourable subsoils (other than carbonates)	<45 cm deep	<60 cm deep
* Avoid soils with seepage	<60 cm deep	<90 cm deep
* Avoid sites with displacement hazard rates of H	X	X
* Avoid sites with surface erosion hazard rating of H (>26 points)	X	X
* Avoid sites with mass wasting hazard ratings of H (>31 points) or greater	X	X
* Avoid sites with forest floor displacement hazards of >19 points[14]	X	X

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[10] Use predominant slope, not average slope; steeper sections shall not exceed 30% with maximum slope length not to exceed 30 m.

[12] Soils with this predominant texture in the rooting zone tend to stick to the roots and produce very large clods of soil.

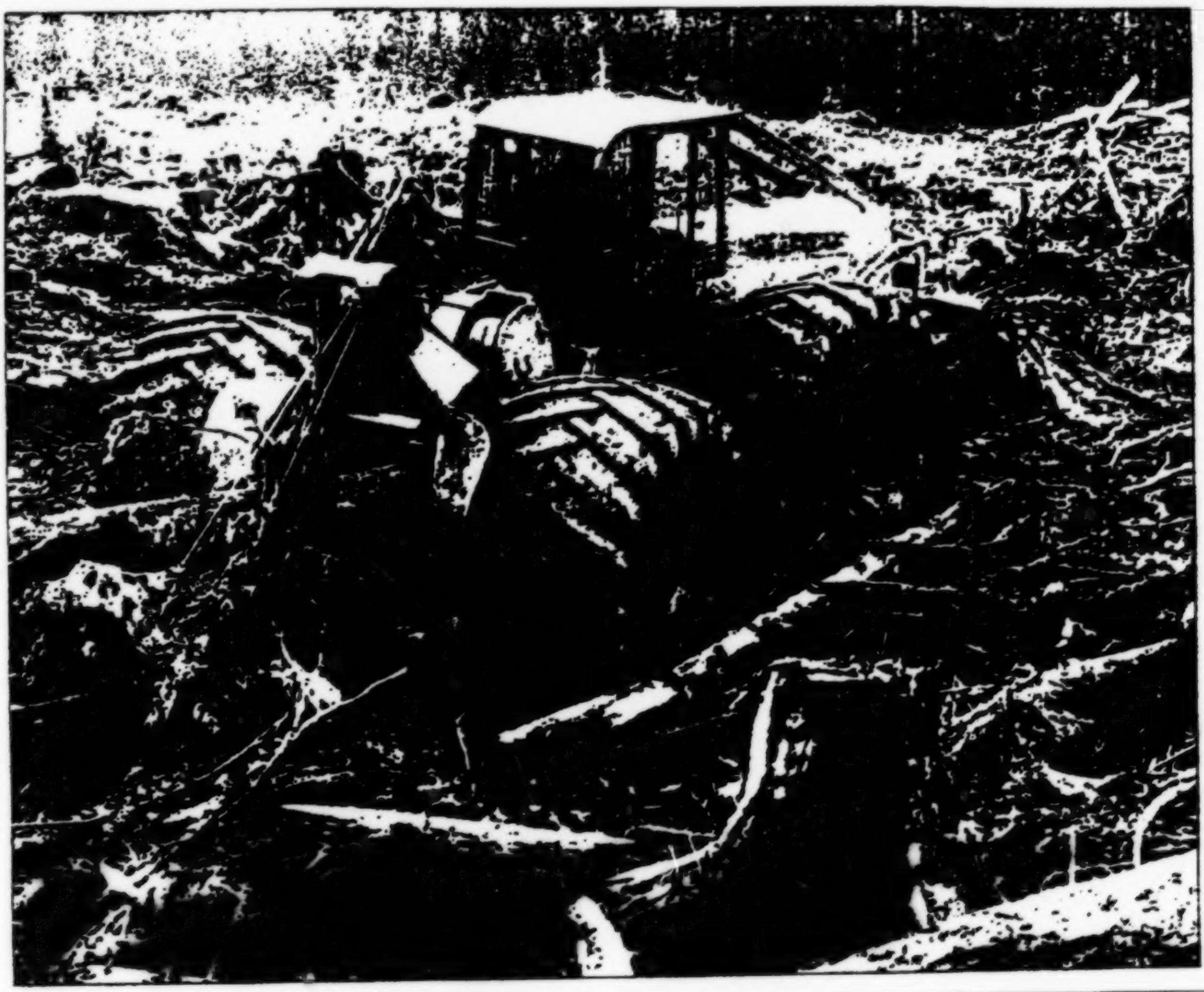
[13] Carbonates occurring on shallower soils (15-30) logging can only be done as an operational Sx trial and must have regional input.

[14] May be a sign to leave stumps on site.

TIMBER HARVESTING

Soil conservation guidelines for timber harvesting

Interior British Columbia



Province of
British Columbia
Ministry
of Forests

Introduction

The Soil Conservation Guidelines are intended to give timber-harvesting operations direction in addressing Silviculture Regulation (B.C. Reg. 147/88, Sec. 2.1 (d) which states that a pre-harvest silviculture prescription (PHSP) shall facilitate the protection of the soil.

The objectives of the Soil Conservation Guidelines are to:

- establish categories of harvesting-related, potentially detrimental soil disturbance;
- establish recognition criteria; and,
- set the maximum allowable levels of potentially detrimental soil disturbance in each category.

Improved pre-harvest planning, better machine operator training, and more careful supervision of harvesting activities will ensure that the long-term productivity of forest soil is maintained and that deleterious off-site impacts are minimized.

The Soil Conservation Guidelines provide direction to pre-harvest planners, engineers, and logging supervisors, and machine operator training. The guidelines apply to road construction, harvesting-related potentially detrimental soil disturbance, and fireguard construction. Potentially detrimental soil disturbance resulting from mechanical site-preparation operations is being addressed by the Forest Service in association with the Interior Forest Harvesting Council — Technical Advisory Committee (IFHC-TAC).

The effectiveness of the guidelines will be assessed by monitoring the extent to which enhanced planning activities and innovative harvesting techniques are implemented. This will be done by measuring the actual levels of potentially detrimental soil disturbance resulting from timber harvesting, and by studying the effects of soil disturbance on site productivity.

Guidelines

The guidelines establish the maximum allowable level of potentially detrimental soil disturbance for any cutblock or treatment unit, and should not be viewed as management targets, but as minimum acceptable standards. Harvesting strategies contained in PHSPs and Logging (Cutting) Plans should strive to ensure that harvesting operations are conducted in a manner that is efficient and creates the least amount of potentially detrimental soil disturbance as possible.

The guidelines specify separate limits on soil disturbances associated with the construction of permanent access (roads and landings) and other potentially detrimental soil disturbances caused by harvesting or fireguard construction activities. This separation reflects the fact that the impact of roads and landings on site productivity is much greater than that resulting from other forestry activities.

The PHSP must contain site-specific information on both the maximum amount of potentially detrimental soil disturbance required for roads and landings, and the maximum amount of other potentially detrimental soil disturbance that will be caused by timber harvesting and fireguard construction activities. The soil disturbance standards specified in an approved PHSP are the standards that will be enforced. Operations which cause soil disturbance in excess of these standards will be subject to penalty.

In order to achieve other substantive management objectives (e.g. harvesting of blowdown, community watersheds, small cutblocks, visually sensitive areas, root rot infestations, uneven-aged stand management, etc.), a PHSP that specifies a higher or lower level of potentially detrimental soil disturbance than is recommended in these guidelines may be authorized.

Higher levels of initial disturbance will only be permitted if the rehabilitation measures specified in an approved PHSP meet the requirements outlined in the Appendix and will result in a reduction of the potentially detrimental soil disturbance levels to a level at or below the maximum allowed.

These guidelines assume that disturbance is uniformly distributed throughout the treatment unit or cutblock, and are not to be interpreted as permitting a heavy concentration of disturbance in localized areas, away from landings and roads.

Soil disturbance hazards

Four harvesting-related, potentially detrimental disturbance hazards are associated with mineral soils:

- compaction and puddling hazard;
- displacement hazard;
- surface erosion hazard; and,
- mass-wasting hazard.

Assessment procedures are described in Land Management Report Number 62.*

Each hazard rating, for every treatment unit identified, must be recorded on the PHSP. The harvesting prescription and logging (cutting) plan submitted for each cutblock must contain strategies that clearly address the most restricting (leading) potentially detrimental disturbance hazards existing within the proposed cutblock. The mass-wasting

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* Lewis, T. et al. 1989. *Developing Timber Harvesting Prescriptions to Minimize Site Degration: Interior Sites*. Victoria, BCMOF. Land Management Report Number 62. 31 pp.

Table 1. Maximum allowable levels of potentially detrimental soil disturbance. These levels do not necessarily equate to equal amounts of loss of site productivity.

Leading soil disturbance	Hazard rating	Roads and landings (% GCA)[a]	Other potentially detrimental disturbance[c] (% NAR[b] by treatment unit)
Mass wasting[d]	VH	7	0
Displacement	VH	7	6
Erosion	VH		
Mass wasting	H		
Compaction	VH		
Mass wasting	M, L	7	13
Displacement[e]	H, M, L		
Erosion[e]	H, M, L		
Compaction	H, M, L		

a GCA = Gross cutblock area (post-harvest)
b NAR = Net area to be reforested
c Other potentially detrimental disturbance refers to skid roads, skid trails, backspar trails, unbladed roadside work areas, and fireguards
d An approved, detailed engineering and road-stabilization plan is required
e When displacement or erosion hazards are high, then bladed skid roads should not exceed six per cent

hazard is a special concern because of the significant risk of deleterious off-site impacts on other resources, structures, and human life.

Roads and landings

Roads and landings are restricted to a maximum of seven per cent of the post-harvest gross cutblock area.

For roadside skidding operations, the disturbed work area parallel to the access roads will be assessed as landing area if the area was stumped and bladed, or if continuous machine traffic has resulted in a running surface similar to a landing, or if the accumulated debris was not adequately eliminated.

Skid roads, skid trails, backspar trails, unbladed roadside work areas, and fireguards

The maximum allowable potentially detrimental disturbance in these skidding-related disturbance classes is calculated as a percentage of the net area to be reforested.

If the mass-wasting hazard is very high, no additional potentially detrimental disturbances beyond that required for access (i.e. roads and landings) are allowed.

If the mass-wasting hazard is high, or displacement, compaction, and erosion hazards are very high, potentially detrimental skidding-related soil disturbances are restricted to six per cent of the net area to be reforested.

For all other combinations of hazard ratings, the maximum allowable level of potentially detrimental skidding-related soil disturbance is restricted to 13 per cent of the net area to be reforested. Where displacement or erosion hazards are high, then bladed skid roads should not exceed six per cent.

Skid roads, backspar trails, and fireguards, rehabilitated to the standard prescribed in the Appendix, will be treated as returned to full productivity and will not be assessed as potentially detrimental disturbances. A commitment to carefully construct these structures, in a manner that will facilitate prompt and adequate rehabilitation, must be stated on the PHSP.

Where soil conditions do not permit full rehabilitation (e.g. unfavourable substrates as specified by Lewis *et al.*) but re-contouring is still considered acceptable in order to recover productive ground buried under sidecast material, the downslope area previously buried will not be assessed as potentially detrimental disturbance. The area that was formerly the cut slope and inner track of the running surface will be assessed as potentially detrimental disturbance.

Definitions

Soil disturbance

Any abrupt change in the physical, chemical, or biological properties of the soil.

Roads

Roads (main haul roads, branch roads, spur roads, and borrow pits) are considered a change in land use, designed to facilitate present and future forest management activities. On slopes, the potential detrimentally disturbed area associated with roads includes the portions of the road profile from the top of the cut to the point on the fill slope where the sidecast material is consistently greater than 15 centimetres deep. On flat ground, the potential detrimentally disturbed area is assessed to the outside of the ditches on either side of the road.

Landings

Areas where logs are decked, processed, sorted, and loaded, and where woody debris is stockpiled. On sloping ground, the landing includes the area from the top of the cut to the portion of the fill slope where the sidecast material is consistently greater than 15 centimetres deep, and the adjacent debris piles. On level terrain, the landing includes the entire area to the outside perimeter of the debris piles if the debris has not been adequately eliminated. If debris has been disposed of, then the area of the main bladed operating surface will be assessed as the landing area.

Debris piles

Large accumulations of woody debris stockpiled around landings and along roadside work areas.

Skid roads

Continuous bladed structures constructed to facilitate ground-based skidding. On sloping terrain, the potential detrimentally disturbed area associated with skid roads includes the area from the top of the cut to the point on the fill slope where the sidecast debris is consistently greater than 15 centimetres deep.

Skid trails

Unbladed travel routes identified by the presence of wheel or track ruts resulting from random skidding with heavy machinery, and/or by extensive uniform compaction indicative of repeated heavy machine traffic over an area (e.g. main trunk skid trails). Criteria for assessing potentially detrimental skid-trail disturbance vary depending on the compaction hazard rating.

Very high, high, or moderate compaction hazard ratings

On sites with very high, high, or moderate compaction hazard ratings, the following are considered potentially detrimental skidding disturbances:

a) Ruts greater than five centimetres deep into mineral soil and greater than 0.3 metres wide x 2.0 metres long, with evidence that heavy machine traffic has caused the development of coarse, platy soil structure and/or dense or puddled soil relative to the undisturbed soil on the site.
Or:

b) Extensive uniform compaction. For a sample point to be assessed as extensive uniform compaction, 75 per cent of the area within a two metre diameter circle encompassing the sample point must show that heavy machine traffic has created coarse, platy soil structure and/or dense or puddled soil relative to the undisturbed soil on the site, and one or more of the following conditions:
   - forest floor and fine slash crushed and/or incorporated into the surface mineral soil;
   - woody debris crushed down into the running surface of the skid trail; and,
   - extensively scalped organic layers resulting in exposed mineral soil.

Low compaction hazard rating

On sites with low compaction hazard, to be assessed as potentially detrimental disturbance ruts must be greater than 15 centimetres deep in the mineral soil and greater than 0.3 metres wide x 2.0 metres long, with evidence of having been created by heavy machine traffic.

Organic soils

On sites with organic soils, to be assessed as potentially detrimental disturbance ruts must be greater than 20 centimetres deep and greater than 0.3 metres wide x 2.0 m long, with evidence of having been created by heavy machine traffic.

Wide gouge

Areas that have been heavily gouged (i.e. 80 per cent of the area within a 1.8 metre x 1.8 metre square has been gouged to a depth of five centimetres or more into the mineral soil) will be assessed as detrimental wide gouge. The wide gouge disturbance category is considered potentially detrimental disturbance for all soil types and hazard classes.

Backspar trails

Backspar trails may or may not be bladed structures. The potentially detrimentally disturbed area associated with bladed backspar trails and other bladed structures related to cable-yarding includes the area from the top of the cut to the point on the fill slope where the sidecast debris is consistently greater than 15 centimetres deep. Unbladed backspar trails will be assessed in the same manner as skid trails.

Fireguards

Fireguards are constructed to facilitate slashburning. If constructed with crawler tractors or backhoes, they are defined in the same manner as skid roads for purposes of measurement.

Gross cutblock area (post-harvest)

Total area within the harvested cutblock boundary. This includes all productive areas (treatment units), natural unproductive areas for timber production (rock, swamp, brush, and alpine forest), and created unproductive areas (new and existing roads, gravel pits, and landings).

Net area to be reforested

Total anticipated area for which basic silviculture requirements exist (including individual types of non-commercial brush of four hectares or less). This is calculated as the sum of the treatment unit areas of the PHSP, i.e. gross block area (post-harvest) minus created and natural unproductive areas.

Soil-disturbance monitoring

Pre-harvest planning, as well as supervision and periodic assessment during operations, will be the most effective method for ensuring that soil-conservation objectives are met and that the Logging Plan is followed.

Upon completion of harvesting operations, a visual inspection of the harvested area will indicate whether or not the allowable level of potentially detrimental soil disturbance has been exceeded. If logging was conducted according to the Logging Plan and the disturbance level appears to be within the acceptable limits, then no survey will be conducted and the area will be determined to be in compliance with the Soil Disturbance Guidelines.

If a visual inspection indicates potentially detrimental disturbance exceeds that allowable, then a ground-based soil-disturbance survey should be conducted. The standardized soil-disturbance survey methodology used by the Forest Service is described in Land Management Handbook, Field Guide Insert 5.[b]

With good planning, adequate contractor training, and conscientious supervision, soil-disturbance surveys should seldom be required.

Appendix - Rehabilitation Requirements

Planning and prescription

Site and soil rehabilitation must be planned in advance to ensure the maximum likelihood of success. Rehabilitation prescriptions must take into consideration those ecological, site and soil factors that affect the feasibility of restoring site productivity.

In recognition of the importance of planning and prescription development to successfully meet the objectives of rehabilitation activities, the following criteria must be met by any proposed harvesting activities that entail initially creating potentially detrimental soil disturbances in excess of the maximum allowed, as specified in Table 1:

1. Appropriate rehabilitation measures must be prescribed in an approved Pre-Harvest Silviculture Prescription (PHSP). The prescription must also contain specifications for skid road, backspar trail or fireguard construction that will facilitate prompt and adequate site rehabilitation and the restoration of site productivity.
2. The Logging (Cutting) Plan must specify the drainage control measures that will be implemented prior to rehabilitation to minimize the risk of erosion during major runoff events.
3. The Logging (Cutting) Plan must indicate those skid roads, backspar trails or fireguards to be rehabilitated, and must specify the methods and procedures that will be followed to rehabilitate the site and restore site productivity.

Construction and rehabilitation

Skid road, backspar or fireguard rehabilitation is most likely to be successful if adequate care is taken during the construction phase to minimize the depth of cut and to place excavated topsoil in a position that will facilitate retrieval during the rehabilitation phase. Skid roads, backspar trails or fireguards, proposed for rehabilitation, must be constructed and rehabilitated with a hoe-type excavator.

A skid road, backspar trail or fireguard is considered to be fully rehabilitated if the following requirements have been met:

- the running surface has been decompacted and outsloped so that downslope subsurface movement of water will not be impeded;

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[b] Curran, M. et al, 1991. *Measuring Soil Disturbance Following Timber Harvesting*. Victoria, BCMOF. Land Management Handbook Field Guide Insert. Number 5. 25pp.

- sidecast material has been returned to the cut surface in a manner which attempts to minimize mixing of productive topsoil and less productive subsoil, and ensures that the topsoil is repositioned at the surface;
- the amount of coarse woody debris mixed into the mineral soil has been minimized;
- sufficient soil is reclaimed to re-establish the original slope profile;
- slash and other organic matter has been deposited on the exposed mineral soil surface; and,
- less that 15 centimetres of continuous sidecast material has been left on the fill side of the original road. The original soil surface on the fill side should not be disturbed unless it has been done in a prescribed manner in order to achieve silvicultural objectives.

Measurement criteria

Soil disturbance survey sample points must be recorded as skid road, backspar trail or fireguard disturbances if they are located on the re-contoured fill between the top edge of the former cutslope and the point where the fill is consistently greater than 15 centimetres deep.

This will generally include the area that was formerly between the top of the cutslope and the midpoint of the running surface. The area from the outer track to the lower edge of the former fillslope will be recorded as "Other" type of disturbance and will not be assessed as potentially detrimental disturbance.

Potentially detrimental disturbance assessment criteria

1. No excavated disturbances are expected on sites with Very High Mass Wasting Hazards so rehabilitation guidelines are not applicable.
2. All skid road, backspar trail or fireguard disturbances, measured in accordance with the definition provided in Measurement Criteria, must be counted as potentially detrimental disturbances for sites with Very High Displacement or High Mass Wasting Hazards.
3. All skid road, backspar trail or fireguard disturbances, measured in accordance with the definition provided in Measurement Criteria, must be assessed as non-detrimental disturbances for sites with Erosion, Compaction or Displacement Hazard ratings of High or less, or Mass Wasting Hazard ratings of Moderate or Low.

NOTES

Province of
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Ministry
of Forests

SILVICULTURE

Interim Soil Conservation Guidelines for Mechanical Site Preparation

Interior British Columbia

DRAFT

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British Columbia

Ministry
of Forests

Introduction

Site preparation plays a significant role in reforestation in British Columbia. From 1981 to 1990 more than 1.2 million hectares of Crown forest land were site prepared.

Mechanical site preparation (MSP) is of particular interest when considering soil disturbance guidelines. The recent increase in MSP, particularly on sites that have traditionally been treated by fire, has increased concern for site productivity.

Limiting the detrimental soil disturbance caused by MSP is the primary objective of these guidelines. Other treatments, such as prescribed burning, can also result in detrimental soil disturbance; however, these will be addressed in subsequent guidelines or in the chapter, *Soil Conservation* in the upcoming Forest Practices Code.

These interim MSP soil conservation guidelines are intended to provide direction to managers responsible for MSP operations in addressing the soil protection requirement in the Silviculture Regulation (B.C. Reg. 147/88, Sec 2.1 (d)). The regulation states that a preharvest silviculture prescription (PHSP) shall facilitate the protection of the soil.

When determining the role site preparation will play in long-term site productivity, the forester must not consider site preparation in isolation. The choice of harvesting method must be determined, and other resource and social objectives must also be considered. These guidelines build on and are intended to be consistent with the *Soil Conservation Guidelines for Harvesting – Interior Sites*. Definitions supplied in the harvesting guidelines apply here and are specified in Appendix 2.

The objectives of MSP include purposeful disturbance of the forest floor and surface mineral soil in order to favourably modify the biological, physical, and microclimatic characteristics of the seedling environment. These guidelines are not intended to restrict well-planned disturbances, which are generally considered to improve site quality. They are to be applied to detrimental disturbance resulting from poorly planned or implemented site preparation treatments. In order to achieve other substantive management objectives (e.g., stumping to treat root rot infections, backlog rehabilitation, maintenance of community watersheds, small cutblocks, or protecting visual areas), a higher or lower level of potentially detrimental disturbance than is recommended in these guidelines may be authorized.

The intent of the attached guidelines is to ensure that long-term site productivity is maintained while ensuring that site preparation decisions meet the following conditions:

- are ecologically based,
- meet management objectives,
- remain operationally feasible, and
- are socially acceptable.

Guidelines

The guidelines establish the maximum allowable level of potentially detrimental soil disturbance and total displacement for any treatment unit and should not be viewed as management targets. Maximum allowable *potentially detrimental soil disturbance* (noted on the PHSP) = potentially detrimental harvesting disturbance + potentially detrimental MSP disturbance. Total potentially detrimental soil disturbance measured after MSP will count both harvesting and MSP disturbance.

Maximum total displacement = all potentially detrimental disturbance plus other scalps and gouges.

These guidelines assume that disturbance is uniformly distributed throughout the treatment unit or cutblock, and must not be interpreted as permitting heavy concentrations of disturbance in localized areas.

Soil disturbance hazards

Site sensitivity to productivity loss is considered in terms of five disturbance hazards (Table 1, columns 1-3). Four hazards are associated with mineral soils and are applicable to both the harvesting and MSP guidelines:

- compaction hazard,
- displacement hazard,
- surface erosion hazard, and
- mass-wasting hazard.

A fifth hazard, the forest floor displacement hazard, is required for determining site sensitivity to MSP.

Where MSP is considered as a treatment option, each hazard rating, for every treatment unit identified, must be recorded on the PHSP. Assessment procedures are described in Land Management Handbook Field Guide Insert 2.

To prevent long-term loss of site productivity, the MSP plan must contain strategies that clearly address the most restricting disturbance hazard. Maximum levels of potentially detrimental soil disturbance and the maximum total displacement allowed on a treatment unit are determined by combining the hazard rating for the leading soil disturbance hazard with the forest floor displacement hazard (see Table 1).

The mass-wasting hazard is a special concern because of the significant risk to off-site resources, structures, and human life. Particular care must also be taken on very high (VH) compaction hazard sites to ensure that planned disturbance will not be potentially detrimental. On many of these sites, any type of scalping may fill with water or channel water to other areas, affecting off-site resource values.

Guidelines

TABLE 1. Maximum allowable levels for potentially detrimental soil disturbance and maximum total displacement

Leading soil disturbance (LSD) hazard[1]	LSD hazard rating[2]	Forest floor displacement hazard	Categories contributing to potentially detrimental[3]	Maximum potentially detrimental disturbance (% NAR[4] by treatment unit)	Maximum total displacement (% NAR by treatment unit)
Mass wasting	VH	NA	All MSP disturbance types (MSP should not occur)	0	0
Displacement	VH	NA	P, WS, CG	6	15
Erosion	VH	NA	P, WS, CG	6	15
Compaction	VH	NA	P, WS	6	25
Mass wasting	H	NA	P, WS, CG	6	25
Erosion[5]	H	NA	P, WS, CG	13	25
All other	All other[6]	VH, H	P, WS	13	30
		M, L	P	13	40

[1] Leading soil disturbance hazard is the most restricting hazard.

[2] LSD hazard ratings: L = low; M = medium; H = high; VH = very high.

[3] Detailed definitions for "disturbance types" contributing to potentially detrimental disturbance are provided under *Definitions* (p. 4) and are illustrated in Appendix 1 (p. 5).

P = *disturbance types considered to be potentially detrimental on all sites*, including very wide scalp, long gouge, wide gouge, and deep gouge, plus potentially detrimental harvesting disturbance, as defined in the harvesting guidelines.

WS = wide scalp; CG = continuous gouge; WS and CG are considered potentially detrimental on more sensitive sites.

[4] NAR = Net area to be reforested.

[5] Maximum potential detrimental is 13%, with bladed skid roads not to exceed 6%.

[6] All other includes all LSD hazard ratings not previously noted in this table (i.e., L, M, H for displacement and compaction plus L, M for mass wasting and erosion).

Categories contributing to potentially detrimental disturbance (Table 1, column 4)

Some disturbances created by MSP will always be potentially detrimental. However, the effect of other disturbances will vary by site. For example, patch scarification on an organically enriched, well-drained sandy loam soil might be very positive; the same treatment on a poorly drained silty clay soil may have serious consequences.

For the purpose of these guidelines, all MSP treatments fall into one of seven "disturbance types." These disturbance types are defined in the *Definitions* section (p. 4). Four of the seven disturbance types are deemed to be potentially detrimental on all sites. These disturbance types are designated by the letter P in Table 1 (see footnote 3). The remaining three disturbance types, the wide scalp, the continuous gouge, and "other scalps," vary by site and may or may not be potentially detrimental.

Table 1, column 4, lists the disturbance types that are potentially detrimental for the various combinations of leading soil disturbance/forest floor displacement hazard ratings. For example, when the LSD hazard rating for displacement is VH, six of the seven MSP "disturbance types" contribute to potentially detrimental disturbance. Only MSP treatments classified as "other scalps" would not contribute to potentially detrimental disturbance. In contrast, when the LSD hazard rating for compaction is M and the forest floor displacement hazard is M, only MSP treatments classified as P contribute to potentially detrimental disturbance. In this case, MSP treatments classified as wide scalps, continuous gouges, or "other scalps" would not contribute to potentially detrimental disturbance. More specifically, a continuous trench, the disturbance often created by a disc trencher, is seen to be potentially degrading on sites where the leading hazard is very high (VH) for mass wasting, displacement, or erosion. However, for sites where the leading hazard is moderate, a continuous trench is not classified as potentially degrading.

Categories contributing to potentially detrimental disturbance also includes all potentially detrimental harvesting disturbance. These disturbance types are listed under *Definitions* (p. 4) and are defined in detail in Appendix 2.

Maximum potentially detrimental disturbance

Maximum potentially detrimental disturbance includes the combined total of harvesting and MSP potentially detrimental disturbances (see Table 1, column 5). It is calculated as a percent of the net area to be reforested by treatment unit (TU). (The 7% allowance for roads and landings outlined in the harvesting guidelines is not included in maximum potentially detrimental disturbance.)

Guidelines

The maximum values allowed for potentially detrimental disturbance in the MSP guidelines are equal to the maximum values in the harvesting guidelines. *Since harvesting disturbance is included when calculating the maximum TU potentially detrimental, this infers that there is no additional allowance for potentially detrimental disturbance associated with MSP.*

The underlying philosophy of the MSP guidelines is that "good" site preparation will not increase potentially detrimental disturbance on the site and will often mitigate detrimental disturbances resulting from harvesting activities. The potentially degrading disturbance categories being targeted are rarely created by good site preparation operations.

While it is recognized that some detrimental disturbance (e.g., rutting) or inappropriate site preparation will occur, it is assumed that this will be offset by the rehabilitation of potentially detrimental harvesting disturbances.

Maximum total displacement

Maximum total displacement (see Table 1, column 6) is based on the net area to be reforested by treatment unit and includes the following:

- total MSP disturbance, including both potentially detrimental and non-detrimental disturbance (i.e., all of disturbance types listed in the following *Definitions* section).

Maximum total displacement also includes:

- skid roads,
- skid trails,
- backspar trails,
- unbladed roadside work areas, and
- fireguards,

as defined in the harvesting guidelines.

Maximum total displacement does not include the following:

- roads and landings,
- disturbance types associated with displacement (e.g., when mounding, the gouge associated with the mound contributes to total displacement but the mound does not. Similarly, for disc trenching, the trench contributes to total displacement but the berm does not), and
- mixtures of humus and mineral soil (e.g., soil disturbance caused by the Madge Rotoclear).

Definitions

The following disturbance types are always considered potentially detrimental and are grouped in Table 1 as the letter P.

Deep gouge: any gouge 30 cm or more into the mineral soil.

Wide gouge: over 80% of a 1.8 × 1.8 metre square area, gouged 5 cm or more into the mineral soil.

Long gouge: any gouge 5 cm or more into the mineral soil along its entire length, and greater than 1 metre in width and 2.5 metres in length.

Very wide scalp: forest floor removed on over 80% of a 3 × 3 metre square.

Potentially detrimental harvesting disturbance: skid roads, skid trails, backspar trails, unbladed roadside work areas, and fireguards, as defined in the *Soil Conservation Guidelines for Harvesting*. These disturbances are also applicable to MSP (e.g., a rut considered potentially degrading for harvesting would also be potentially degrading if created during site preparation). These disturbance types are defined in Appendix 2.

The following disturbance types will always contribute to total disturbance but will only be considered potentially detrimental on more sensitive sites as indicated in Table 1.

Wide scalp: forest floor removed on over 80% of a 1.8 × 1.8 metre square.

Continuous gouge: any gouge into the mineral soil, greater than 3.5 metres long and gouged to mineral soil along the entire length.

Other scalps: minor scalps and gouges that expose mineral soil but are too small to fit into the above categories.

Soil disturbance monitoring

A good site preparation prescription that is properly implemented, combined with appropriate equipment, well-trained operators, and periodic assessment during operations, will be the most effective method of ensuring that soil conservation objectives are met.

Upon completion of MSP, a visual inspection of the treated area will confirm whether or not the allowable level of potentially detrimental soil disturbance has been exceeded. If the approved treatment method has been followed and the disturbance level appears to be within the acceptable limits, then no survey will be conducted and the area will be determined to be in compliance with the soil disturbance guidelines.

If a visual inspection indicates that potentially detrimental disturbance exceeds that allowable, then a ground-based soil disturbance survey should be conducted. The standardized soil disturbance survey methodology used by the Ministry of Forests is described in *Measuring Soil Disturbance Following Mechanical Site Preparation, Field Guide Insert* draft.

These guidelines are not intended to replace common sense. Certain types of disturbance not targeted by these guidelines can be detrimental. These include deep mixing on sites with unfavourable subsoil, removing excessive amounts of coarse woody debris, mixing on very steep slopes, and some kinds of organic soil disturbance. Local experience and professional judgement are required in these special cases.

Appendix 1. Potentially Detrimental Disturbances

The four disturbances illustrated first are represented in Table 1 by the letter P. These disturbances are always considered potentially detrimental. They include:

- Deep gouge,
- Wide gouge,
- Long gouge, and
- Very wide scalp.

The last two disturbances illustrated in this appendix are:

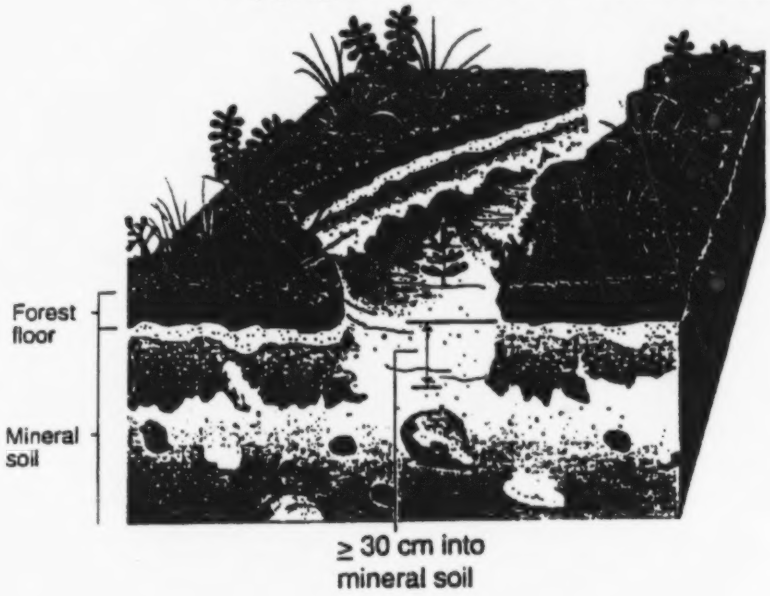
- Wide scalp, and
- Continuous gouge.

They are identified in Table 1 by the letters WS and CG, respectively, and are considered potentially detrimental on sensitive sites only.

Other scalps and gouges are not illustrated.

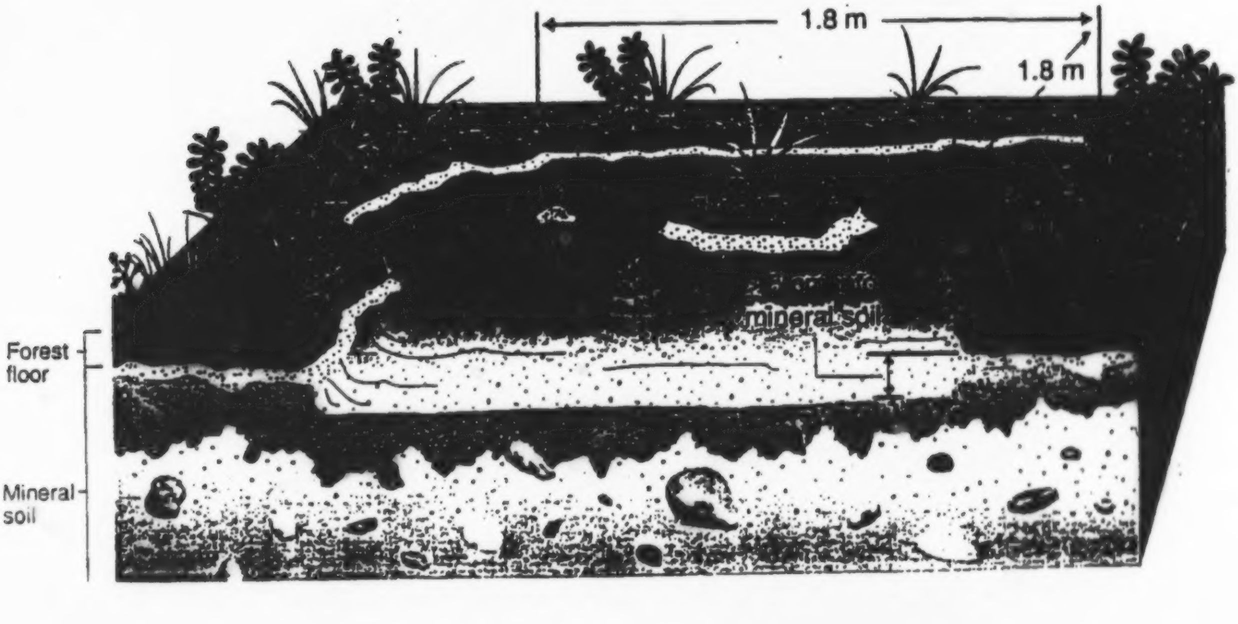
Deep Gouge

Any gouge 30 cm or more into the mineral soil


Forest floor
Mineral soil
≥ 30 cm into mineral soil

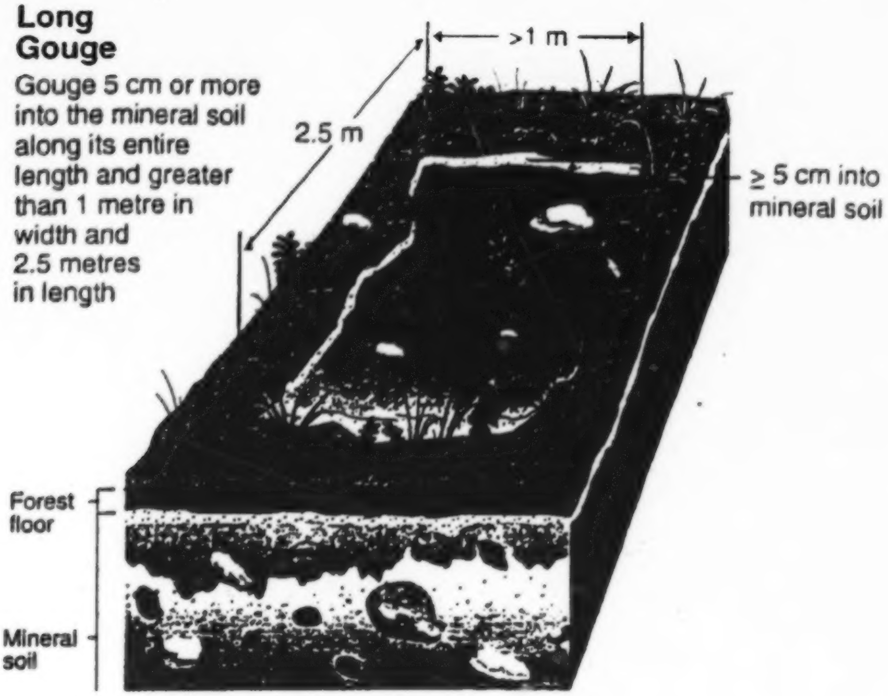
Wide Gouge

Over 80% of a 1.8 by 1.8 metre square area gouged 5 cm or more into the mineral soil


1.8 m
1.8 m
≥ 5 cm into
mineral soil
Forest floor
Mineral soil

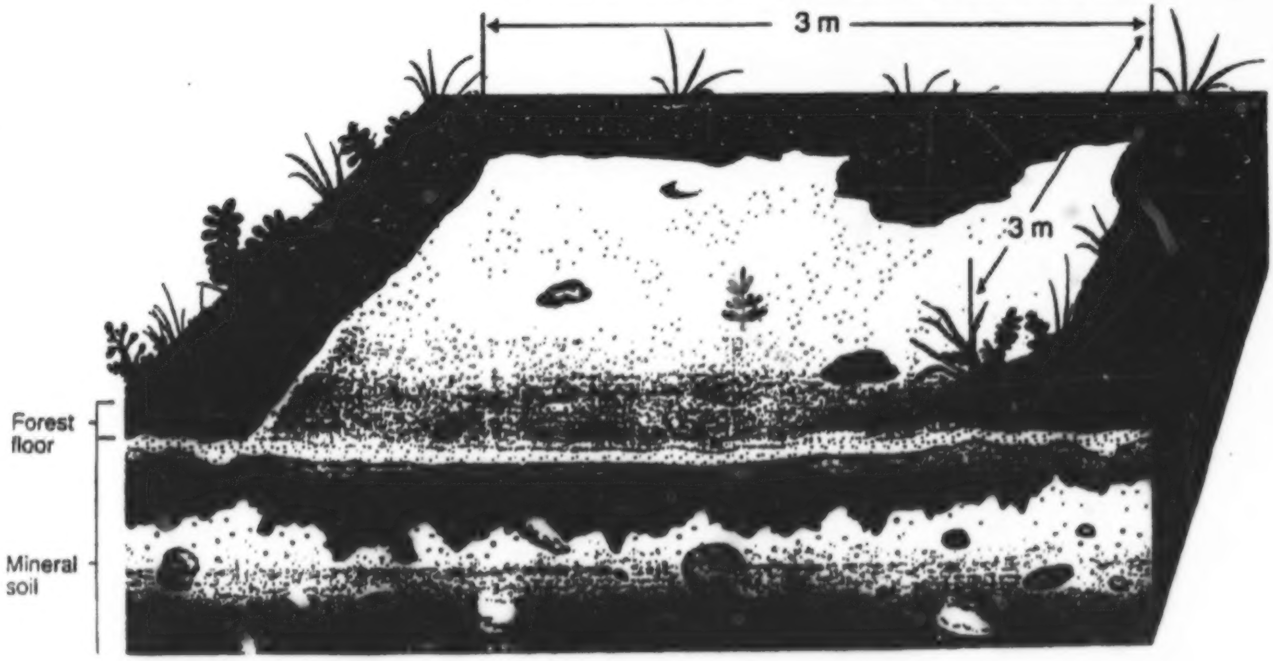
Long Gouge

Gouge 5 cm or more into the mineral soil along its entire length and greater than 1 metre in width and 2.5 metres in length


>1 m
2.5 m
≥ 5 cm into mineral soil
Forest floor
Mineral soil

Very Wide Scalp

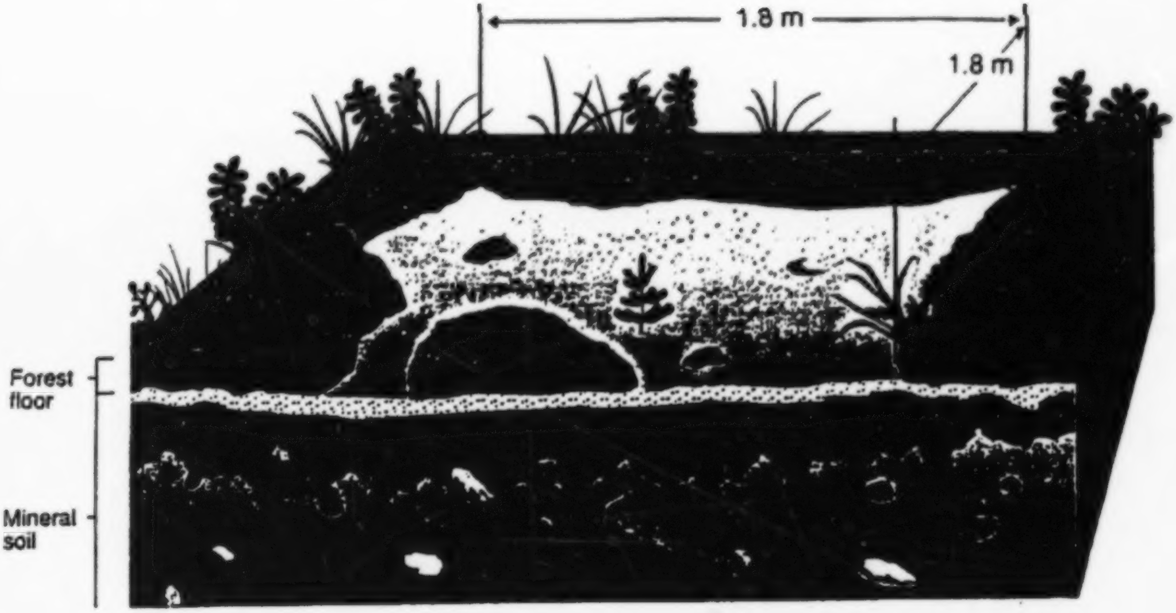
Forest floor removed on over 80% of a 3 X 3 metre square


3 m
3 m
Forest floor
Mineral soil

(WS)

Wide Scalp

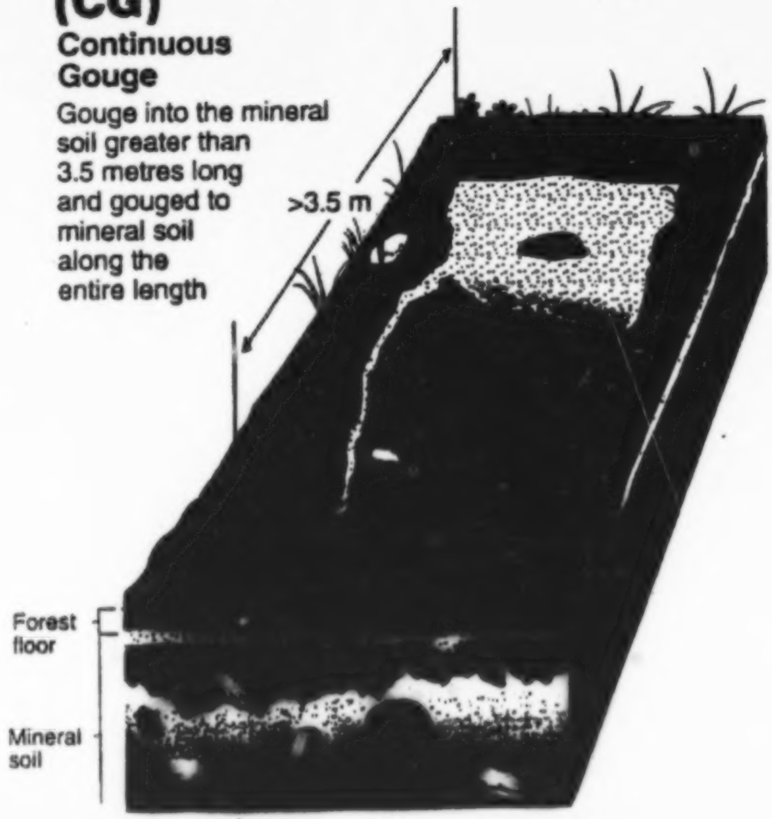
Forest floor removed on over 80% of a 1.8 X 1.8 metre square


1.8 m
1.8 m
Forest floor
Mineral soil

(CG)

Continuous Gouge

Gouge into the mineral soil greater than 3.5 metres long and gouged to mineral soil along the entire length


>3.5 m
Forest floor
Mineral soil

Appendix 2. Definitions from *Soil Conservation Guidelines for Timber Harvesting – Interior British Columbia*

Soil disturbance Any abrupt change in the physical, chemical, or biological properties of the soil.

Potentially detrimental soil disturbance Soil disturbance that reduces site productivity or places other resources at risk. In the context of these guidelines, potentially detrimental soil disturbance refers to haul roads, bladed skid roads, compacted skid trails, landings and associated debris piles, heavily disturbed roadside work areas, bladed backspar trails, and fireguards.

Roads Roads (main haul roads, branch roads, spur roads, and borrow pits) are considered a change in land use, designed to facilitate present and future forest management activities. On slopes, the potentially detrimental disturbed area associated with roads includes the portions of the road profile from the top of the cut to the point on the fill slope where the sidecast material is consistently greater than 15 cm deep. On flat ground, the potentially detrimental disturbed area is assessed to the outside of the ditches on either side of the road.

Landings Areas where logs are decked, processed, sorted, and loaded, and where woody debris is stockpiled. On sloping ground, the landing includes the area from the top of the cut to the portion of the fill slope where the sidecast material is consistently greater than 15 cm deep, and the adjacent debris piles. On level terrain, the landing includes the entire area to the outside perimeter of the debris piles if the debris has not been adequately eliminated. If debris has been disposed of, then the area of the main bladed operating surface will be assessed as the landing area.

Debris piles Large accumulations of woody debris stockpiled around landings and along roadside work areas.

Skid roads Continuous bladed structures constructed to facilitate ground-based skidding. On sloping terrain, the potentially detrimental disturbed area associated with skid roads includes the area from the top of the cut to the point on the fill slope where the sidecast debris is consistently greater than 15 cm deep.

Skid trails Unbladed travel routes identified by the presence of wheel or track ruts resulting from random skidding with heavy machinery, and/or by extensive uniform compaction indicative of repeated heavy machine traffic over an area (e.g., main trunk skid trails).

Criteria for assessing potentially detrimental skid-trail disturbance vary depending on the compaction hazard rating.

Very high, high, or moderate compaction hazard ratings On sites with very high, high, or moderate compaction hazard ratings, the following are considered potentially detrimental skidding disturbances:

a. **Ruts greater than 5 cm deep into mineral soil and greater than 0.3 m wide × 2.0 m long, with evidence that heavy machine traffic has caused the development of coarse, platy soil structure and/or dense or puddled soil relative to the undisturbed soil on the site.**

Or:

b. **Extensive uniform compaction.** For a sample point to be assessed as extensive uniform compaction, 75% of the area within a 2 m diameter circle encompassing the sample point must show that heavy machine traffic has created coarse, platy soil structure and/or dense or puddled soil relative to the undisturbed soil on the site, and one or more of the following conditions:

- Forest floor and fine slash crushed and/or incorporated into the surface mineral soil.
- Woody debris crushed down into the running surface of the skid trail.
- Extensively scalped organic layers resulting in exposed mineral soil.

Low compaction hazard rating On sites with low compaction hazard, to be assessed as potentially detrimental disturbance ruts must be greater than 15 cm deep in the mineral soil and greater than 0.3 m wide × 2.0 m long, with evidence of having been created by heavy machine traffic.

Organic soils On sites with organic soils, to be assessed as potentially detrimental disturbance ruts must be greater than 20 cm deep and greater than 0.3 m wide × 2.0 m long, with evidence of having been created by heavy machine traffic.

Wide gouge Areas that have been heavily gouged (i.e., over 80% of the area within a 1.8 m × 1.8 m square has been gouged to a depth of 5 cm or more into the mineral soil) will be assessed as detrimental wide gouge. The wide gouge disturbance category is considered potentially detrimental disturbance for all soil types and hazard classes.

Backspar trails Backspar trails may or may not be bladed structures. The potentially detrimental disturbed area associated with bladed backspar trails and other bladed structures related to cable-yarding includes the area from the top of the cut to the point on the fill slope where the sidecast debris is consistently greater than 15 cm deep. Unbladed backspar trails will be assessed in the same manner as skid

Appendix 2. Definitions from *Soil Conservation Guidelines for Timber Harvesting – Interior British Columbia*

Fireguards Fireguards are constructed to facilitate slashburning. If constructed with crawler tractors or backhoes, they are defined in the same manner as skid roads for purposes of measurement.

Gross cutblock area (post-harvest) Total area within the harvested cutblock boundary. This includes all productive areas (treatment units), natural unproductive areas for timber production (rock, swamp, brush, and alpine forest), and created unproductive areas (new and existing roads, gravel pits, and landings).

Net area to be reforested Total anticipated area for which basic silviculture requirements exist (including individual types of non-commercial brush of 4 ha or less). This is calculated as the sum of the treatment unit areas of the PHSP, that is, gross block area (post-harvest) minus created and natural unproductive areas.

APPENDIX C - Preliminary Discussion on the Role of Stumps in the Ecosystem

Armillaria ostoyae has been identified as a widespread pathogen in the Nelson Forest Region. Given preliminary research which indicates increased timber production can be achieved through stump removal (Morrison *et al.* 1988), this technique has the potential to become a prominent treatment. Prior to the extensive implementation of any new MSP treatment, however, the proposed benefits must be weighed and balanced against potential impacts to ecosystem components on a site sensitivity basis.

Stump removal treatments involve either the off-site removal or the on-site above-ground displacement of stumps and larger roots. The potential effect(s) of this management treatment on the functional role of stumps in the ecosystem needs to be reviewed. The following is a very brief review of pertinent literature; further detail is required.

BIOMASS

Information in the literature on stump and large root biomass is limited. to a great extent, this reflects the fact that they are difficult to measure. Further, the available information is highly variable due to the use of different definitions of stump height and the inclusion of different root sizes (Keays 1971).

Table 1 summarizes a portion of the information presented in Young *et al.* (1964) and Keays (1971) on stump-root biomass.

Table 1. Stump-root biomass

Species	Dia. (cm)	Height (m)	Merchantable Bole (kg)	Stump, Large & Medium Roots (kg)	% Stump & Roots of Merch. Bole	Source
Red Spruce	33.0	18	280	107	38	Young *et al.* 1964 [a]
Abies balsamea	15.2	15	30	8	27	Young *et al.* 1964
Abies balsamea	25.4	18	103	30	29	Young *et al.* 1964
Abies balsamea	33.0	18	174	59	34	Young *et al.* 1964
Tsuga canadensis	15.2	15	37	9	23	Young *et al.* 1964
Tsuga canadensis	25.4	15	104	34	33	Young *et al.* 1964
Tsuga canadensis	33.0	18	211	75	35	Young *et al.* 1964
White Pine	33.0	18	288	87	30	Young *et al.* 1964
Tsuga heterophylla	15.2	ng	ng	ng	23	Eis 1974 cited in Keays 1971 [b]
Tsuga heterophylla	25.4	ng	ng	ng	33	Eis 1974 cited in Keays 1971

ng = not given

[a] (unclear if bark is included)

- stump: portion of the bole from ≅ 15 cm above ground extending downward to the place where the large roots are apparent
- merchantable stem: bole of the tree from the stump to an upper limit of 10 cm in dia.
- large roots: roots larger than 10 cm to base of stump
- medium roots: roots from 2.5 - 10cm in diameter
- oven dry weights include bark

[b] (bark is not included)

- stump: portion of bole to ≅ 30 cm above ground
- full tree bole = merchantable stem
- no definition for root component

The biomass (dry) of the stump-root system generally represents from 20-35% of the merchantable tree biomass for medium and large diameter trees, with the proportion of the stump-root system decreasing with decreasing diameter. For smaller diameter trees (<10cm dbh), this trend is reversed and the stump-root represents a significantly higher proportion of the total tree biomass with decreasing tree diameter (Keays 1971).

On a stand basis (kg/ha), Malkonen (1974) reported that stumps and roots[1] represented from 23 to 27% of the total stem biomass for three Scots pine stands ranging in age from 28-47 years. For three 100-year-old jack pine stands, Johnston (1971) reported that stumps and roots[2] represented from 20-30% of the total stem biomass/site. On these sites the stump-root systems equaled from 21-42 mT/ha (oven dry mass). The 42 mT/ha was just less than one-quarter the total above-ground biomass for that particular stand (245 mT/ha). Both studies used bulldozers to extract the stump. The above mentioned stump-root masses should therefore be fairly comparable to those operationally extracted in stump removal treatments.

The proportion of the total stand biomass represented by the stump-root system is determined by such factors as: species, diameter and height, site characteristics, stand density, windthrow and dominance (Keays 1971).

ECOSYSTEM ROLES

Literature on the function(s) of stumps in the ecosystem is limited. It is however reasonable to assume that the ecological functions of stumps are similar to those of coarse woody debris (CWD). Coarse woody debris is identified as a critical component of the ecosystem contributing to site productivity, and to site structural and functional diversity (Harvey *et al.* 1980; Harvey 1982; Jurgensen *et al.* 1990; Amaranthus *et al.* 1989; Franklin *et al.* 1989; Harvey *et al.* 1987; Ruggiero *et al.* 1991; Perry *et al.* 1989; Hunter 1990; Harmon *et al.*1988; Harvey *et al.* 1981).

SITE PRODUCTIVITY

Stumps and CWD contribute to site productivity as long-term sources of nutrients and organic matter and habitat.

Total Nutrient Capital

Information on the total nutrient content of stumps is limited. In general, total nutrient contents are low relative to other tree components. For a 45-year-old Scots pine stand in Finland, stumps and roots (>1 cm dia.) represented from 4-8% of the total stand capital for nutrients such as N, K and Ca (Malkonen 1974).

As early as the 70s, the shift in the forest industry away from "sawlog" to whole tree harvesting raised concerns in the scientific community about the potential effects of off-site nutrient displacement on long-term site productivity (Kimmins 1977; Johnson *et al.* 1982; Kellomaki and Seppala 1987). Since then, research has demonstrated greater nutrient losses associated with whole tree compared to sawlog harvesting. These losses represent a significant proportion of the "available", but a much smaller portion of the total soil pool.

The scientific community acknowledges that an assessment of the long-term impact of whole tree harvesting is complicated, because it depends on many interrelated site and stand factors (e.g., site quality, rotation length and species composition). Even though the consequences cannot be predicted with confidence, there is consensus that, combined with short rotations and intensive stand tending (i.e., thinning), whole tree harvesting (intensive biomass removal) may result in site productivity losses (Kellomaki and Seppala 1987; Kimmins 1987).

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[1] roots divided in <1 cm and ≥1 cm dia. classes; percentage based on roots >1 cm dia.

[2] included most roots - no diameter breakdown provided

Conventional tree harvesting (removal of all above-ground tree biomass from the site) combined with the off-site removal of the stump-root system meets the definition of complete tree harvesting (Kimmins 1987). Complete tree harvesting therefore has an even greater potential for nutrient losses than conventional harvesting. Even so, as discussed above, the potential impact of off-site stump removal on total nutrient capital will depend on the size of other site nutrient pools and on the effect of organic mater losses on nutrient cycling between the pools.

Organic Matter & Nutrient Recycling

Stumps, CWD and derived soil organic matter are important in maintaining an active population of soil fauna which directly influences site productivity through nutrient recycling (Harmon *et al.* 1986; Harvey *et al.* 1989; Battigelli *et al.* 1994). Important links between the health of the above- and below-ground ecosystems are discussed in several recent reviews (Molina and Armaranthus 1991; Shaw *et al.* 1991).

The decay process from stump or CWD to soil organic matter involves a myriad of soil organisms which are responsible for nutrient and carbon recycling within the ecosystem. Since the decay process takes decades, stumps and CWD represent both a short- and long-term reservoir of nutrients and carbon (Jurgensen et al. 1990; powers 1989a; Harvey et al. 1989). Further, CWD has been shown to accumulate nutrients, in particular nitrogen, through litterfall, throughfall, nitrogen fixation and fungal colonization (Caza 1991). Rates of asymbiotic nitrogen fixation average 1 kg/h/year across a wide range of forest types (Harmon et al. 1986). For example, Larsen et al. (1979) estimated asymbiotic nitrogen fixation in above-ground decayed woody residues for a Douglas-fir stand at 735 g N/ha/year. While input levels of N from this source are low, accrual over a rotation can be significant (Larsen et al. 1979; Jurgensen 1990). This accrual is important in the Pacific Northwest where nitrogen availability is generally low.

The importance of soil organic matter in maintaining site productivity is well documented in the literature. Negative impacts on short-term tree growth due to organic matter losses through forest floor and surface soil displacement are reported in several windrow and scalping trials (Bosworth and Studer 1991; Balneaves and Dyck 1992; McColl and Powers 1989; Powers 1989; Weber *et al.* 1984). The long-term impacts of soil organic matter losses on tree growth are less well understood; tree growth is also dependent on many site specific characteristics (e.g., soil type and moisture regime) (Edmonds *et al.* 1989) and research results do not yet span a full rotation..

Other Benefits of Organic Matter (& Organic Matter Precursors)

Soil organic matter is a key factor in enhancing soil structure and imparting resilience against permanent change (Powers 1989b). Soil porosity, which is directly related to soil structure, influences soil aeration and water infiltration. Poor aeration and infiltration can reduce tree growth and accentuate soil degrading processes such as erosion, compaction and mass wasting during management treatments.

ECOSYSTEM DIVERSITY

CWD and stumps contribute to ecosystem structure and in doing so enhance the biotic diversity of the ecosystem (FEMAT 1993). The role of CWD in providing habitat for many species of plants, fungi, invertebrates, amphibians (e.g., salamanders), reptiles and small mammals are reviewed in many recent publications (e.g., FEMAT 1993; Ruggiero *et al.* 1991; Caza 1993; Harmon *et al.* 1986).

In the forest ecosystem, CWD provides habitat and a long-term source of energy and nutrients for a broad range of invertebrates (e.g., bark beetles, wood borers, termites, carpenter ants) and soil flora and fauna. As habitat CWD provides varied, stable microsites. The water-holding capacity of CWD helps to buffer major temperature and moisture fluctuations, and thereby provides alternate habitats when normal habitats are adverse (Shaw *et al.* 1991; Harvey *et al.* 1987). Downed woody debris also provides spatial and temporal continuity of habitat (Harmon *et al.* 1986; Harvey 1982).

Research in the interior Northwest forests and elsewhere have demonstrated a strong relationship between CWD and mycorrhizal fungi and free living soil N-fixing bacteria (Harvey *et al.* 1987; Amaranthus *et al.* 1989). The importance of N-fixing bacteria as a source of nitrogen is discussed above. The importance of the conifer-mycorrhizal symbiotic relationship is well document in improving seedling survival and water and nutrient uptake (Amaranthus *et al.* 1989; Trappe and Bollen 1981). Maintaining adequate continuous sources of CWD at various stages of decay is important to maintain mycorrhizal populations as well as other beneficial organisms.(Amaranthus *et al.* 1989).

Decaying and decayed woody debris is also used by a large number of vertebrates for cover, feeding, reproduction, and behaviours such as resting, preening, bedding, lookouts, drumming, sunning, bridging, roosting and hibernating (Harmon *et al.* 1986; Maser and Trappe 1984). In some forest ecosystems, decayed CWD also serves as habitat for natural regeneration (Harmon *et al.* 1986; Maser and Trappe 1984).

Of the literature reviewed, few studies reported on the specific function(s) of stumps in the ecosystem. Specific reference was found on stump use by salamanders (eggs laid under bark) (Dubuis 1993), chipmunks (Hunter 1990), microarthropods (e.g., collembola) (Setala and Marshall 1994), and woodpeckers (insect foraging during periods of low sources of food) (M. Ladd, pers. comm., 1993[3]).

DEVELOPMENT OF GUIDELINES

Forest ecosystems evolve with a continuous although variable influx of CWD. The amount and timing of this input reflects factors including forest type, successional stage, forest age and the amount of mortality (e.g., insects, disease, wind) (Graham *et al.* 1991). This natural succession similarly applies to stumps. Under a conventional clear-cut harvesting scenario, long-term sources of organic matter include downed logs, stumps, snags and leave trees. The volume of large woody debris retained must be sufficient to carry-over well into the next rotation to ensure long-term site productivity and biodiversity are maintained(Maser *et al.* 1988).

The acknowledged importance of CWD in maintaining long-term site productivity and ecological diversity is reflected in the recent development of post-harvest CWD retention guidelines in several U.S. National Forests (Eubanks 1989; Harvey *et al.* 1987), and the current development of CWD guidelines in B.C.[4] In western Montana ecosystems, post-harvest retention guidelines range from 22-36 mT/ha of CWD (Harvey et al. 1987). These guidelines are in addition to stumps. Based on Johnstone's (1971) biomass study of 100 year old jack pine stands, the stump-root system represented up to 42 mT/ha.

Even if left on site following extraction, the ecological function of a stump will be altered at least for the mid-term. Exposure of stumps and large roots to the air will lengthen the decay process due to drying and increased temperature extremes (Larsen *et al.* 1989). The decay process will also be reduced by the limited contact with the soil or other wood residues which permit vegetative hyphae inoculation (Larsen *et al.* 1989).

The existing *Armillaria SOP Site Sensitivity Guidelines* provide an initial site sensitivity rating system for stump removal. The potential impact of stump removal or displacement on the above- and below-ground ecosystems requires further review and discussion.

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APPENDIX D - Comparison of Disturbance Categories since 1991

Soil Disturbance Definitions

- (c = compacted nc=not compacted)

	1993 Cat.	Defn.	Call[1]	Det.[2]	1992 Cat	Defn.	Call	Det.	1991 Cat	Defn.	Det.
Cut & Fill Skid Rds	R	count cut bank, running surface and berm from top of cut to where *wd or mineral <15 cm*	P&O	Y	R	cout cut bank and running surface from top of cut to where *wd <15 cm or mineral <5 cm*	P&O	Y	R	count cutbank and running surface from top cut to where wd<15 cm or mineral <5 cm	Y
▨	▨	▨	▨	▨	B skid rd.	count where continuously *mineral >15 cm or wd >30 cm*	P&O	Y	B	count where continuously mineral >5cm or wd>15cm	Y
Heavy Traffic Equiv. to Bladed	We	extensive scalping: *@ pt. & >80% of 2 m circle* >5 cm scalp (compaction not required)	P&O	Y	We	extensive scalping: *@ pt. & >80% of 1.8x1.6 m* area >5cm scalp (compaction not required)	P&O	Y	R	bladed areas on skidtrails >5cm deep over >1.5 x 1.5m area were counted as skid roads	Y
Cribbed WoodyDebris on Running Surface(Equiv. to HX/HFc)	HD[2]	≥15 cm cribbed & crushed wd (compaction and scalping not requred)	P&O	under review	Be	≥15 cm (compaction and scalping not requred)	P&O	N	B	see defn. above	
Ruts - M-VH Comp.Haz	TE/TF c	>.3x 2m L rut *& compaction evidence*[3] *@ pt. & >5 cm deep @ max Xsect.* (& along entire length)	P&O	Y	1	>.3 x 2 m L rut *& compaction evidence & > 5 cm deep @ max Xsect.* (& along entire length)	P&O	Y	1 2	(for noncohesive soils) >15cm @ max X sect. (compaction present or not; no dia. or length requirements) OR (for cohesive soils) >10cm @ max Xsect. (compaction present or not; no dia. or length requirements)	Y Y
Ruts - L Comp. Haz	TE/TF c	>.3 m x 2 m L rut *& compaction evidence @ pt. & >15 cm deep @ max Xsect.* (& along entire length)	P&O	Y	3	>.3 m x 2 m L rut *& >15 cm deep @ max Xsect.* (& along entire length)	P&O	Y	3	(for noncohesive soils) >15cm @ max X sect. (compaction present or not; no dia. or length requirements)	Y
Impress - M-VH Comp.Haz	IE/IF c	<.3x2m impress *& compaction evidence @ pt. & >5 cm @ max. Xsect.* (& along entire length)	P&O	Y	L	see defn below	P	N	1	(for cohesive soils) >5cm @ max. Xsect. (compaction present or not; no dia. or length requirements)	Y
Impress - L Comp. Haz	IE/IF c	<.3x2m impress. *& compaction evidence @ pt. & >15 cm @ max. Xsect.* (& along entire length)	P&O	Y					3	((for oncohesive soils) >15 cm @ max Xsect (compaction present or not; no dia. or length requirments)	Y
Ruts - L-VH Comp. Haz	TE/TF nc	>.3x2m L rut & *>5 (M-VH)* OR*>15 cm (L) @ max. Xsect.* (& along entire length)	P&O	N	L	see defn below		N	1	(for cohesive soils) >5cm @ max Xsect. (compaction present or not; no dia. or length requirements)	Y
	L	see definition below	P&O	N					3	(for noncohesive soils) >15 cm @ max X sect. (compaction present or not; no dia. or length requirements)	Y
Impress - L-VH Comp.Haz	IE/IFnc	<.3x2m impress. &*>5 (M-VH)* OR *>15 cm (L) @ max. Xsect.* (& along entire length)	P&O	N	L	see defn below		N	1,2,or3	(for cohesive soils) >5 or 10 cm; (for noncohesive soils) >15cm @ max Xsect. (compaction present or not; no dia. or length requirements)	Y
	L	see definition below		N					1 or 3	(for cohesive soils) >5 cm or (for noncohesive soils) >15 cm @ max Xsect. (compaction present or not; no dia. or length requirments)	Y
Organic Soils									4		Y

	1993 Cat.	Defn.	Call[1]	Det.[2]	1992 Cat	Defn.	Call	Det.	1991 Cat	Defn.	Det.
Heavy Traffic main trunk skid trail	HE/HF c	main trunk skid trail with *compaction evidence @ pt. & visually extensive*[4] over 75% of a 2 m radius circle		Y	H H*[5]	main trunk skid trail with *compaction evidence @ pt. & visually extensive* over 65% of a 2 m radius circle above but compaction evidence = compaction+platiness	P&O	Y	R or 1 or L	see other defns.	
					M*i	main trunk skid trail *compacted but not platy @ pt. & visually extensive* over 65% of a 2 m radius circle	P&O	N			
	HE/HF nc	main trunk skid trail with *visually extensive criteria* over 75% of a 2 m radius circle BUT no compaction evidence @ pt.		N	M*i M*ii	main trunk skid trail *compacted but not platy @ pt. & visually extensive* criteria over 65% of a 2 m circle OR main trunk skid trail *not compacted or platy @ pt. & visually extensive* criteria	P&O	N			
Moderate Traffic evidence of extensive machine traffic which results in a less severe impact than H,1,3 (used in NFR benchmark & PO surveys)	L	see defn. below (M categories were not used in provincial surveys)	P	N	L	see defn below	P	N	L	see other defns.	
	ME/MF1 c	≥ 6x2m long disturbance <5 cm with *compaction evidence @ pt.*	P&O	N							
	ME/MF2 c	*compaction evidence @ pt. & visually extensive* but<75% of 2 m circle	P&O	N	M M*ii M*i	*compaction evidence & visually extensive* machine traffic but <65% of 2m circle, OR *not compacted or platy @ pt. & visually extensive*> ≤65% of 2m circle OR *compacted not platy @ pt. & visually extensive*> ≤65% of 2m circle	P&O	N			
	ME/MF1 nc	≥ 6x2m long disturbance <5 cm *(no compaction@ evidence @ pt).*	P&O	N	L L M*i M*ii	see defn below see defn below *compacted but not platy @ pt. & visual extensive* > ≤65% of 2m circle OR *not compacted @ pt. & visually extensive* > ≤65% of 2m circle	P P P&O	N N N			
	ME/MF2 nc	*visually extensive* BUT <75% of 2 m circle(no compaction evidence @ pt.)	P&O	N							
Light Distrubance	LE/LF c	machine traffic <5 cm, not meeting the criteria for H or M with compaction evidence (ie., ≤3 passes)	P	N	L	machine traffic which has created an impression < above dimensions (includes compaction and scalping)		N	L	machine disturbance < above; includes deposits of mineral soil or woody debris not associated with an intact skid rd. berm/sidecast or not meeting the depth requirement for B	N
	LE/LF nc	machine traffic <5 cm, not meeting the criteria for H or M with no compaction evidence (ie., ≤3 passes)	P	N							
	L	light machine traffic not meeting criteria for other categories	P	N							

	1993 Cat.	Defn.	Call[1]	Det.[2]	1992 Cat	Defn.	Call	Det.	1991 Cat	Defn.	Det
Other Scalps	OS	minor scalps not included in other categories	P	N	OS	minor scalps	P	N	O	other machine disturbance < above; includes deposits of mineral soil or woody debris not associated with an intact skid road berm/sidecast or not meeting the depth requirements for B	N
Undisturbed	U	undisturbed areas - includes surfaces beneath stumps which can be observed	P	N	U	undisturbed areas - includes surfaces beneath stumps which can be observed	P	N	U	includes light ff disturbance not attributable to light machine traffic; also if assessment beneath slash or large logs is not possible it is recorded as U (unless obviously something else, eg. skid rd)	N
(>70% mineral)	D		P	N	D		P	N	L	see other defn.	N
Plantable Mineral Deposits	D1,2,3	5-15cm,15-30cm,>30cm	P	N	Dtr,Dc,D	>30cm >30% mineral,15-30cm,>30cm	P	N			
Loose Brush	B1,2,3	15-30cm,30-80,>80cm	P	N							
Mixture of WoodyDebris & Mineral : Not Good Planting Media	X1,2,3	5-15cm,15-30,>30cm	P	N	X	poor mixtures of soil & woody debris, not good planting medium >30 cm	P	N			
Piles	P	≥3.x3.m x .5 m deep pile of slash debris that are not associated with landings	P	N	P	≥3.x3.m x .5 m deep pile of slash debris that are not associated with landings	P	N	O	see other defn.	N

	1993 Cat.	Defn.	Call[1]	Det.[2]	1992 Cat	Defn.	Call	Det.	1991 Cat	Defn.	Det
LSDH							MSP Sens.		no MSP		
Deep Gouge	G(referred to as G1)	gouge≥30 cm @ pt	P	Y: all cases	G	≥30 deep gouge in the immediate vicinity of pt. (ie., within 50 cm of pt, which must occur on the same gouge)	P&O	Y: all cases			
	G2	gouge ≥20 cm @ pt & within 50 cm of ≥30 cm depth	P&O	N							
Stump Hole	ST	≥10 cm @ pt but doesn't meet G1,G2 or W criteria	P	N	OS	see defn.	P&O	N			
Wide Gouge	**WG**	pt & >80% of 1.8 x 1.8 m is gouged >5cm	P&O	Y: all cases	**WG**	pt & >80% of 1.8 x 1.8 m is gouged >5cm	P&O	Y: all cases			
Long Gouge	LG	gouge >5cm @ max. depth & >1x2.5m long	P&O	Y: all cases	OS	see defn. above	P&O	N			
Very Wide Scalp	**VWS**	ff removed @ pt & >80% 3x3m	P&O	Y: all cases	**VWS**	ff removed @ pt & >80% 3x3m	P&O	Y: all cases			
Wide Scalp	**WS**	ff removed @ pt & >80% 1.8x1.8m	P&O	Y if 6.	**WS**	ff removed @ pt & >80% 1.8x1.8m	P&O	Y if: EH,VH, M			
Continuous Gouge	CG	gouge >3m long (no depth criteria)	P&O	Y if:7	CG OR OS	continuous gouge >5 cm @ max. Xsect. & >3 cm long (depth along entire length) gouges <5 cm	P&O	Y if: EH,VH, H			

1. "Status Quo" : standard classification of disturbances as potentially detrimental
2. HD used in NFR 1993 benchmark surveys
3. **compaction evidence for 1+H categories:** coarse platey and/or massive soil structure AND/OR dense or puddled soil relative to the undisturbed;
4. **visually extensive:** for H category in addition, one or more of the following a. forest floor and fine slash crushed or incorporated into the surface mineral soil woody debris crushed down into running surface of heavy traffic skid trail; c. extensive scalping of ff resulting in exposed soil
5. ***different compaction definition**; i., ii., iii., = different M categories
6. Y if :Displacement VH; Erosion VH,H; Compaction VH; Mass Wasting H. Y in all other cases if:FFDH VH,H
7. Y if:Displacement VH; Erosion VH,H, Mass Wasting H

Note: bold = provincial categories

APPENDIX E - Assumptions in 1992 Calculations

To improve the interpretative value of the 1992 survey results, and in doing so to improve comparability with the 1993 survey results, treatment unit specific "adjustment factors" were used based on the following assumptions about the 1992 surveys:

1. heavy traffic disturbances meeting the less restrictive 1993 definition for compaction were classified as moderate traffic soil disturbance (M);
2. stump holes meeting the 1993 ST category criteria were classified as an "other scalp" (OS); and,
3. on certain treatment units, the non-compacted scalped heavy skid trails (not meeting the wide scalp criteria) represented significant forest floor displacement.

To provide some measure of how restrictive the 1992 compaction definition was, four of the 1993 treatment units were surveyed using both the 1992 and 1993 compaction definitions. The following table summarizes the results.

Comparison of disturbance using the 1992 and 1993 compaction definitions.

TU	Treatment	Season	% of 1993 compaction calls meeting the more restrictive 1992 compaction criteria	1992 adjustment factor for compaction based on the less restrictive 1993 criteria
Chatter	ST	winter	9.5	0.91
Wetask	ST	summer	5.1	0.95
Lardeau	PO	winter	46.6	0.53
Slewiskin	PO	winter	3.7	0.96

Field observations during the 1993 surveys suggested these adjustment factors percentages were high. Based on the field observations, the limited sample size, and the wide range of factors other than treatment and season which can influence soil compaction, a decision was made not to use the above percentage "adjustment factors." Instead, a subjective, two-tiered system was used to increase the 1992 estimate of soil compaction. For treatment units with common and infrequent compaction, 25% and 50% respectively of the 1992 moderate traffic (M) soil disturbance was assigned to the compacted heavy traffic soil disturbance category (Hc).

The proportion of the 1992 OS category assigned to the stump hole ST category was derived from the 1993 data. The "adjustment factor" was based on the average ratio of the 1993 ST category to the combined 1993 OS+ST categories. For the 1993 stumped and summer and winter PO logged treatment units, the 1993 ST category represented 84 (6.1), 90 (3.1), 75 (12.0)% (SEm) of the combined OS+ST disturbances. These averages were used to assign a proportion of the 1992 OS category to the new ST category.

Lastly, field observations indicated significant surface soil exposure on non-compacted heavy skid trails on two sites. For these two sites, 50% of the M disturbance category was included in the total displacement calculation.

Since the 1992 definition of a gouge (G) encompassed the 1993 G and G2 soil disturbance categories, the 1992 less restrictive definition "status quo" total potentially detrimental soil disturbance based on the 1992 definition included more disturbance than the equivalent 1993 assessment. In 1992 deposits in gouges were not recorded. Under the more restrictive potentially detrimental disturbance definition, all stump holes were classified as potentially detrimental in 1992 regardless of depth of plantable mineral deposit.

APPENDIX F - Timber Harvesting Disturbances

BACKGROUND

In 1993 forest floor scalping and compaction were recorded at each sample point. This provided an opportunity to evaluate these two characteristics for all timber harvesting disturbance categories.

RESULTS AND DISCUSSION

Skid Roads (R) & Heavy Traffic Skid Trails (compacted Hc and uncompacted H)

Of the heavy traffic disturbances, bladed skid roads (R) and compacted heavy traffic skid trails (Hc) were considered potentially detrimental. As shown in Figure 1, bladed skid roads (R) occupied less than 3% of the NAR, with the exceptions of E.Kidd (3.6%) and Mt. Seven summer (13.7%).

Heavy traffic disturbance generally increased in the following order: summer PO > winter PO > stumped. For summer PO treatments, heavy traffic disturbance (H+Hc) ranged from 5.9-14.1 % of NAR. For the winter PO and stumped treatments, respectively, heavy traffic disturbance ranged from 3.1-9.3% and 0.7-3.5% of NAR. See Table 1.

In general, the proportion of total heavy traffic disturbance that was compacted, while more variable than the total, increased as follows: summer PO > winter PO > stumped. For the summer PO treatments 58-73% of the heavy traffic disturbance was compacted (Hc). For the winter PO and stumped treatments, respectively, the proportion of heavy traffic compacted ranged from 16-59% and 46-63 % (of total).

The proportion of heavy traffic disturbance with displaced forest floor increased in the following general order: summer PO > winter PO ≅ stumped.

For conventionally harvested blocks, Thompson and Osberg (1991) also reported significantly higher timber harvesting disturbance on summer versus winter harvested blocks (all harvesting categories were included). Winter harvesting on frozen soils or a snowpack reduces the potential for soil compaction as well as forest floor scalping.

Based on field observations at two summer PO treatment units (Colepitts and Mt. Seven s), D. English[5] suggested that in some cases points tallied as compacted heavy skid trails may include areas where only the excavator had traveled and that non-compacted heavy skid trails may include paths created by timber being winched to the skidder, or areas used for swivel drags. For both treatment units, the timber sale license (TSL) specified designated trails (20 m distances) for skidding. Reasons for other differences between the summer treatment units are unclear.

The lower timber harvesting disturbance, and less compaction, associated with summer stumping compared to summer PO logging may reflect the fact that PO logging involves moving the whole tree whereas only parts of the tree are moved at any one time during stumping. Partitioning the tree reduces ground pressure and the potential for soil compaction.

On sites with high compaction and/or high forest floor displacement hazard, winter PO should be favoured over summer PO, until further information is available.

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[5] D. English, Small Business Program, Golden Forest District

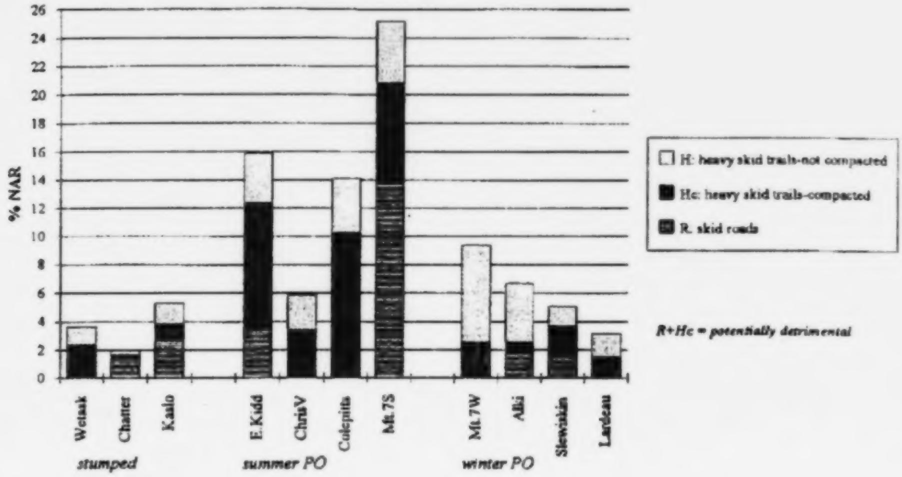

Figure 1 Skid Road & Heavy Traffic Disturbance

Heavy Traffic Skid Trails with Woody Debris Deposits

Woody debris deposits are relatively common on heavy traffic skid trails, particularly with winter harvesting. These deposits are often cribbed into the surface soil. In the Nelson Forest Region (NFR), consideration is being given to classifying heavy traffic skid trails with a >15 cm cribbed woody debris deposit as potentially detrimental, irrespective of whether the underlying mineral soil is compacted or scalped.

As shown in Table 2, only a relatively small proportion of the heavy traffic skid trails were covered with >15 cm cribbed woody debris. For nine of the treatment units, the per cent of heavy skid trails covered with >15 cm cribbed woody debris varied between 0-4%. For the remaining two treatment units, deposits of >15 cm cribbed woody debris occurred on 11% (Alki) and 13% (Mt 7w) of the total heavy skid trails. These treatment units were winter harvested with designated skidding.

For all treatment units, over 90% of the skid trails beneath the cribbed woody debris are neither compacted (HF) nor scalped (HE). In this situation, the early build-up of woody debris serves as a mat protecting the underlying soil. Under the provincial timber harvesting guidelines these sample points are recorded as a non-detrimental light disturbance.

Table 1. Skid roads and heavy skidding disturbance (% of NAR)

System	Stumped			Pushover Logged				Pushover Logged				Stumped		Pushover			
Season	Summer	Winter		Summer				Winter				Summer+ Winter		Summer		Winter	
Skidding Pattern	R	D	R	R	R	D	D	R+D	R+D	R	R+D						
TU	Wetask	Chatter	Kaslo	E.Kidd	ChrisV.	Colepit	Mt.7	Mt.7	Alki	Slewisk	Lardeau	Mean	SEm	Mean	SEm	Mean	SEm
R	0.1	1.3	2.6	3.6	0.0	0.0	13.7	0.1	1.7	1.7	0.0	1.3	0.7	4.3	6.5	1.0	0.5
HE	0.2	0.3	0.6	0.9	0.6	1.0	1.3	1.7	0.6	0.2	0.2	0.4	0.1	0.9	0.3	0.6	0.4
HEc	0.9	0.4	0.2	6.4	1.3	6.2	4.5	1.3	0.4	1.2	0.7	0.5	0.2	4.6	2.4	0.8	0.2
HF	1.1	0.1	0.9	2.7	1.8	2.8	3.1	5.1	3.6	1.2	1.5	0.7	0.3	2.6	0.5	2.4	0.9
HFc	1.3	0.0	1.0	2.4	2.1	4.1	2.6	1.2	0.4	0.8	0.8	0.8	0.4	2.8	0.9	0.8	0.2
Tot.H+Hc	3.5	0.7	2.6	12.3	5.9	14.1	11.5	9.3	5.0	3.4	3.1	2.3	0.8	10.9	3.6	4.6	1.4
Tot.Pot.Det.	2.3	1.6	3.8	12.3	3.4	10.3	20.8	2.5	2.5	3.7	1.5	2.6	0.7	11.7	7.2	2.5	0.5
%Hc	63	57	46	71	58	73	62	27	16	59	48						
%HE	31	93	31	59	32	51	50	32	20	41	29						

E = forest floor removed; F = forest floor intact @ point and over object

c = compacted

S= summer; W=winter; R=random; D=designated

The proposed reclassification of skid trails+cribbed woody debris as a potentially detrimental category reflects the width and linear nature of heavy skid trails and the likelihood that the cribbed woody debris is an integral feature of this classification. While it may be arguable whether the cribbed woody debris directly degrades soil productivity, research studying ecosystem response to the respread of 10 cm of wood chips reported significant reduction in planted seedling survival and growth, absence of understory vegetation regrowth, absence of regeneration, toxic flux of phenols during the first two years, and acidification of the forest floor (Schmidt and Lotan 1979; DeByle 1979). Other indirect effects may include insulation resulting in lower spring soil temperatures[1] and reduced soil gaseous exchange. Regardless of the cause of the reduced productivity, extensive woody deposits >15 cm represent an unfavourable growing environment which requires rehabilitation to restore potential productivity.

The negative impact of woody debris deposits on tree growth is implied in the Forest Practices Code. Soil Conservation Standards, which require the rehabilitation of "areas greater than 10 m^2 in extent where >80% of the area has >15 cm deep compacted deposits of forest floor, fine slash, and woody debris overlaying or crushed into the mineral soil " (FPCS 1994).

Non-cribbed woody debris deposits >15 cm deep also occur on heavy skid trails[2]. In the 1993 surveys, woody debris deposits >30 cm were relatively uncommon and typically over lay non-compacted or scalped mineral soil. The rationale for reclassifying an extensive cribbed woody debris deposit, however, also applies for extensive deep non-cribbed woody deposits. A re-evaluation of the classification of woody deposits >15 cm deep on heavy skid trails is required.

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[1] Field observations: Bill Watt, Pedologist, Cariboo Forest Region, Williams Lake, B.C.

[2] Percentages of X1 and X2, non cribbed woody debris deposits, were not individually determined.

Table 2. Partitioning of heavy traffic based on woody debris deposits (% of NAR)

	Stumped			Pushover Logged				Pushover Logged				Stumped		Pushover Logged			
Season	Summer	Winter		Summer				Winter				Summer+ Winter		Summer		Winter	
Skidding Pattern	R	D	R	R	R	D	D	R+D	R+D	R	D						
Site	Wetask	Chatter	Kaslo	Kidd	ChrisV	Colp	Mt.7s	Mt.7w	Alki	Slewiskin	Lardeau	Mean	SEm	Mean	SEm	Mean	SEm
H+Hc+X1,2ncr	3.4	0.7	2.5	11.8	5.9	14.0	10.9	7.5	4.4	3.3	3.1	2.2	0.8	10.6	3.5	4.1	1.0
HFX3ncr	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.4	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
HEX3ncr	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HFcX3ncr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HEcX3ncr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HFX2cr,3cr	0.1	0.0	0.0	0.4	0.0	0.0	0.3	1.0	0.5	0.0	0.0	0.0	0.0	0.2	0.2	0.3	0.2
HEX2cr,3cr	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
HFcX2cr,3cr	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HEcX2cr,3cr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Heavy Traffic	3.5	0.7	2.6	12.3	5.9	14.1	11.5	9.3	5.0	3.4	3.1	2.3	0.9	10.9	3.8	4.6	1.5
%of Heavy Traffic with X3ncr	0.0	0.0	3.7	1.2	0.0	0.0	1.5	6.3	1.6	2.3	0.0	1.2	1.2	0.7	0.8	2.3	1.3
%of Heavy Traffic with Xcr	2.1	0.0	0.0	2.9	0.0	0.5	4.0	13.2	10.6	0.0	0.0	0.7	0.7	1.8	1.9	4.9	3.5

S=summer; W=winter; R=random; D=designated;

cr= cribbed woody debris deposits; ncr = noncribbed woody debris deposits;

1 <15 cm; 2 15-30 cm; 3 >30 cm woody debris deposits

Moderate Traffic

The 1993 definitions of moderate traffic were

- ME1[3], MF1: 60 x 200 cm, <5 cm deep (compacted and not compacted)
- ME2, MF2: skid trail meeting the visual criteria but not areal extent (80% of a 2 m circle) of a skid trail (compacted and not compacted)

These definitions addressed single tire and track related disturbances (M1), and objects such as narrow heavy skid trails and edges of skid trails, in other words the gradations between the heavy and light traffic areas (M2).

On average, moderate traffic disturbances occupied 2, 11 and 12% of the NAR, respectively, for stumped, summer PO and winter PO operations (Figure 2). The M2 categories represented the largest proportion of this type of disturbance and were largely unscalped (MF2). The two winter PO treatment units with a random skidding pattern had a noticeably higher per cent of M2 compared to the designated skidding treatment units. The influence of skidding pattern on these disturbance categories requires further examination. A similar relationship between random and designated skidding is not apparent on the summer PO treatment units. The compacted M2 categories represented on average 2, 3 and 3% of the NAR respectively for the stumped, summer PO and winter PO treatment units.

In the absence of moderate traffic disturbance categories at a provincial level, these disturbances are classified as light traffic. The inclusion of the compacted moderate disturbances in the light disturbance category should be revisited. The M2 categories in particular are relatively large objects. Given that they are created by machine traffic, it is likely the compaction extends throughout much of the object and does not simply occur at an isolated point as implied by the light traffic (Lc) category.

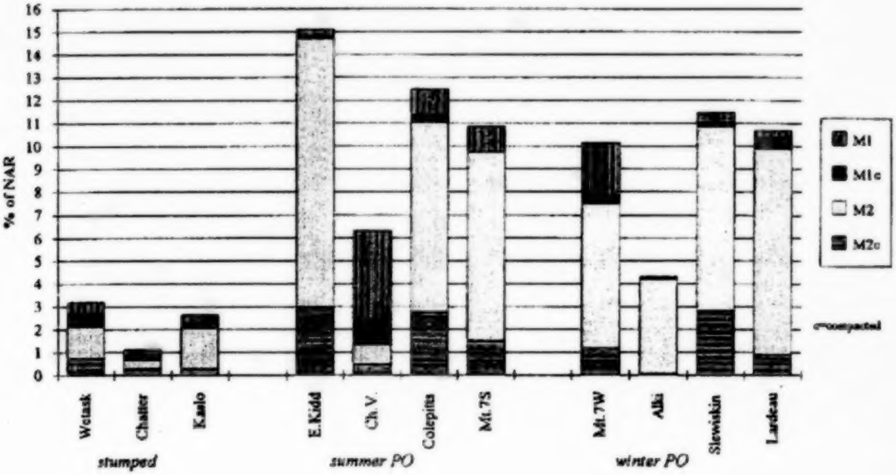

Figure 2 Moderate Traffic Disturbance

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[3] E = scalped; F = forest floor intact

Table 3. Moderate traffic (% of NAR)

	Stumped		
Season	Summer	Winter	
Skidding Pattern	R	D	R
Site	Wetask	Chatter	Kaslo
ME1	0.2	0.1	0.2
MF1	0.3	0.2	0.2
ME2	0.3	0.1	0.3
MF2	1.1	0.2	1.5
ME1c	0.2	0.1	0.0
MF1c	0.4	0.1	0.2
ME2c	0.1	0.1	0.0
MF2c	0.7	0.2	0.3
sumM1	1.1	0.5	0.6
sumM2	2.1	0.7	2.1

Pushover Logged			
Summer			
R	R	D	D
E.Kidd	Ch.V.	Colepit	Mt.7s
0.0	0.3	0.1	0.4
0.3	3.6	1.0	0.7
4.8	0.1	0.8	3.5
6.9	0.8	7.4	4.7
0.0	0.1	0.3	0.0
0.1	1.0	0.0	0.0
1.9	0.1	0.6	0.8
1.1	0.3	2.2	0.7
0.4	5.0	1.5	1.1
14.7	1.3	11.0	9.7

Pushover Logged			
Winter			
R+D	R+D	R	D
Mt.7w	Alki	Slewisk	Lardeau
0.6	0.0	0.2	0.0
1.7	0.1	0.3	0.3
1.8	0.5	2.1	1.3
4.5	3.6	5.9	7.6
0.2	0.0	0.1	0.1
0.1	0.0	0.1	0.3
0.6	0.0	1.2	0.0
0.6	0.1	1.6	0.9
2.6	0.1	0.6	10.7
7.5	4.2	10.8	21.4

Stumped Summer+ Winter		Pushover Summer		Logged Winter	
Mean	SEm	Mean	SEm	Mean	SEm
0.2	0.0	0.2	0.2	0.2	0.2
0.2	0.0	1.4	1.5	0.5	0.4
0.2	0.1	2.3	2.2	1.2	0.3
0.9	0.4	5.0	3.0	4.5	0.9
0.1	0.1	0.1	0.2	0.1	0.0
0.2	0.1	0.3	0.5	0.2	0.1
0.1	0.0	0.8	0.7	0.4	0.3
0.4	0.1	1.1	0.8	0.7	0.3
0.7	0.2	2.0	2.0	3.0	2.5
1.6	0.5	9.2	5.6	9.1	3.7

c = compacted, R = random, D = designated

Light Traffic Disturbance and Undisturbed

As shown in Figure 3, light traffic fell primarily in the non-scalped, non-compact (LF) category. Overall light traffic increased in the following order: PO winter (31-51%) ≅ PO summer (29-48%) > ST (21-36% NAR).

The area undisturbed ranged from 6-28% of the NAR. Based on averages, the proportion of the NAR left undisturbed increased in the following order (mean:range): stumped (23: 17-27%) > PO winter (18: 6-28%) > PO summer (12: 7-24% NAR). Additional attention should be given in soil disturbance surveys to the proportion of the area left undisturbed.

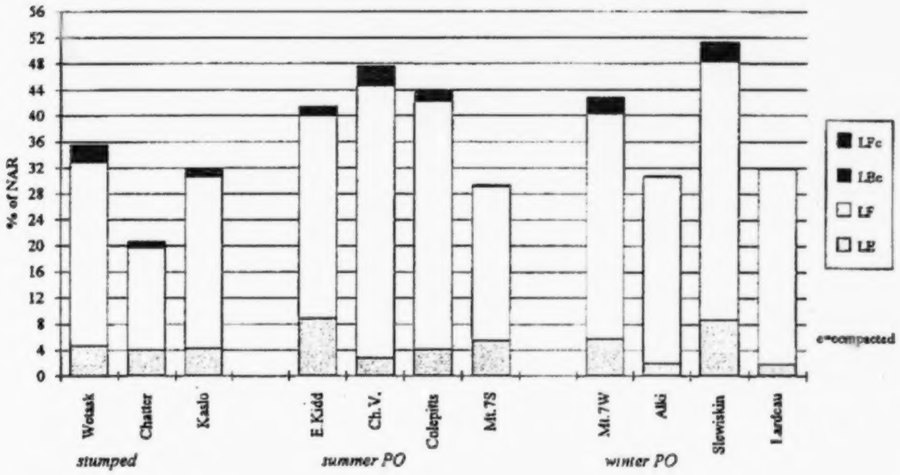

Figure 3 Light Traffic Disturbance

APPENDIX G - 1992 & 1993 Landings and Roads

Background

The *NFR Soil Conservation Standard Operating Procedures (SOP)* (NFRT 1994) guideline maxima for landings are summarized in Table 1. In the case of small blocks, the *NFR Soil Conservation SOP* states "under 5 ha, carefully scrutinize and try to maximize utility through use by other treatment units and cut-blocks...". In accordance with the *Timber Harvesting Guidelines* (BCMF 1993b), the *SOP* specifies 7% of gross cut area (GCA) as an average (i.e., average of working forest within a watershed) maximum for roads and landings.

The following table summarizes information on roads and landings for the treatment units surveyed in both years, using the above guidelines for reference.

Table 1. Road and landing guidelines in the *NFR Soil Conservation SOP*

GCA (ha)	**Maximum Landing size (% of GCA)**	**Maximum Area for Roads & Landing (% of GCA)**
>10	3	7
<10 >5	3	7
<5	minimize size	7

Results & Discussion

Landings were not measured on three of the 19 treatment units surveyed. Another three of the cut-blocks included a conventional and an *Armillaria* treatment unit (see Tables 4 and 5 in the main report). Figure 1 presents the % of GCA in landing(s) for the 16 treatment units. As shown in this figure, landings occupied from 1.9% to 16% of the GCA.

Figure 2 presents roads and landings as a % of the GCA for the remaining treatment units. As shown in this figure, roads and landings ranged from 1.8% to 30.9% of the GCA (Table 2). Obvious trends between season and operation are not apparent. Seven of the treatment units were in compliance with the *Timber Harvesting Guideline* 7% maximum for roads and landings (BCMF 1993b). It is, however, acknowledged that special conditions, which are not taken into account here, may have resulted in a higher percentage permitted in the PHSP.

The above results indicate that in some cases additional attention needs to be given to discussing the importance of minimizing landing size at the pre-work conference, and to periodic assessments during operations.

X in "compliance" with NFR Soil Conservation SOP

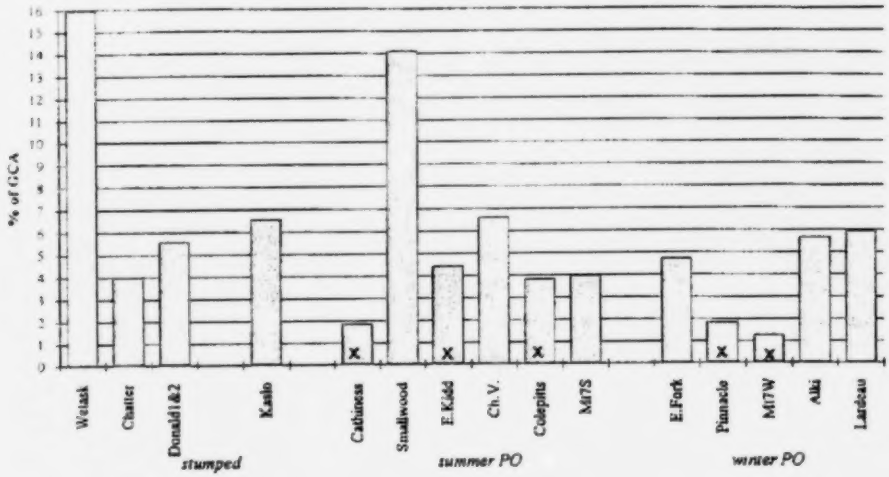

Figure 4 1992 & 1993 Surveys - % of CGA as Landing

X in compliance with Timber Harvesting Guidelines - 7% of GCA

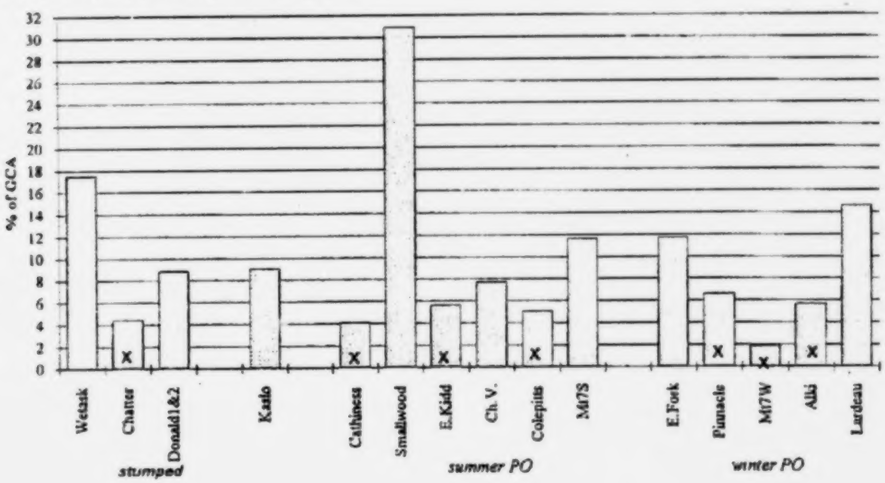

Figure 5 1992 & 1993 Surveys - % of GCA as Roads & Landings

Table 2. Summary of % of GCA as landings and roads

TU	Year	Seas.	Tr.	No. Treatment units (No. surveyed)	GCA	Spur Rds /Haul Rds (ha)	Landings (ha)	NAR TU1 (ha)	NAR TU2 (ha)	Proportion of GCA as TU1	NFR SOP Landing Size Max. (ha)	% of GCA as landing	% of GCA as landing & roads
Wetask	93	S	ST	1	2.6	0.04	0.42	2.1	na	na	min[1]	16.0	17.5
Chatter	94	S	ST	2(1)	11.3	0.05	0.45	5.8	5.0	0.5	3	4.0	4.4
Donald1&2	92	S	ST	1	10.2	0.33	0.57	7.9	1.4	na	3	6.6	9.2
Kaslo	93	W	ST	1	11.0	0.27	0.72	10.0	na	na	3	6.6	9.0
ChrisV+++	92	S	PO	1	5/16.5	0.00	0.00	5.0	na	na	4	na	na
Pepper Cr.+	92	S	PO	1	4.0	0.02	0.35	4.0	na	na	min	na	na
Cathiness	92	S	PO	1	19.5	0.44	0.36	18.7	na	na	3	1.9	4.1
Smallwood	92	S	PO	1	4.2	0.71	0.59	2.9	na	na	min	14.1	30.9
E.Kidd*	93	S	PO	1	4.2	0.05	0.19	4.0	na	na	min	4.4	5.6
ChrisV.	93	S	PO	1	30.3	0.33	2.00	28.0	na	na	3	6.6	7.7
Colepitts	93	S	PO	1	7.0	0.09	0.27	6.6	na	na	4	3.8	5.1
Mt7S	93	S	PO	2(2)	11.4	0.88	0.45	8.5	1.6	0.7	3	3.9	11.7
E.Fork++	92	W	PO	1	18.5	0.72	0.48	9.0	na	na	3	4.7	11.8
Pinnacle	92	W	PO	1	30.3	1.44	0.56	28.3	na	na	3	1.9	6.6
Mt7W	93	W	PO	2(2)	6.4	0.04	0.08	4.3	2.0	0.7	4	1.3	1.8
Alki	93	W	PO	1	7.6	0.00	0.43	7.2	na	na	4	5.7	5.7
Slewiskin**	93	W	PO	1	5.0	0.00	0.00	5.0	na	na	4	na	na
Lardeau	93	W	PO	1	3.1	0.27	0.18	2.6	na	na	min	5.9	14.6
Average												6.3	10.0
SEm												1.0	1.8

1992: + harvesting not completed; ++ blowdown salvage therefore no assigned landing; +++ estimated GCA

1993: * landing is across the haul road and was used by another cut-block; ** landing in another cut-block used

[1] for blocks <5 ha the reation is to minimize landing size as much as possible

APPENDIX H - Stump Hole Dimensions

Stump Hole Sizes for 1993 Pushover/Stumped Blocks ***area dimensions, standard deviations & standard errors***

	centimeters			square meters	cubic meters	
	axis 1	axis 2	depth	Area (M2)	Volume (M3)	
NSLEWISKIN	107	112	40	1.20	0.34	
	110	130	40	1.43	0.40	
	90	70	35	0.63	0.15	
	106	110	34	1.17	0.28	
	111	119	50	1.32	0.46	
	82	165	44	1.35	0.42	
	161	183	43	2.95	0.89	
	100	161	30	1.61	0.34	
	120	150	30	1.80	0.38	
	160	200	40	3.20	0.90	
	150	140	45	2.10	0.66	
	130	110	45	1.43	0.45	
	100	120	40	1.20	0.34	
Mean	117.5	136.2	39.7	1.90	0.54	
STDsamp	25.6	35.2	6.0	0.70	0.22	
StdError	7.4	10.2	1.7	0.20	0.06	n = 13
CHRISTIANV	170	150	80	2.55	1.43	
	85	110	30	0.94	0.20	
	145	150	20	2.18	0.30	
	165	130	50	2.15	0.75	
	110	210	30	2.31	0.49	
	36	72	18	0.26	0.03	
	64	62	30	0.40	0.08	
	113	168	37	1.90	0.49	
	142	122	43	1.73	0.52	
	122	74	28	0.90	0.18	
	270	143	46	3.86	1.24	
	137	82	50	1.12	0.39	
Mean	129.9	122.8	38.5	1.60	0.46	
STDsamp	59.4	44.8	16.9	1.10	0.37	
StdError	17.1	12.9	4.9	0.30	0.11	n = 12
COLEPITTS	150	185	45	2.78	0.87	
	166	145	45	2.41	0.76	
	115	175	40	2.01	0.56	
	135	175	50	2.36	0.83	
	142	146	53	2.07	0.77	
	180	145	35	2.61	0.64	
	168	145	35	2.44	0.60	
	168	145	35	2.44	0.60	
	220	230	60	5.06	2.13	
	190	120	50	2.28	0.80	
	220	170	35	3.74	0.92	
	140	130	40	1.82	0.51	
	260	190	80	4.94	2.77	
Mean	173.4	161.6	46.4	3.0	1.08	
STDsamp	40.6	29.6	12.9	1.2	0.80	
StdError	11.3	8.2	3.6	0.3	0.22	n = 13

	centimeters			square meters	cubic meters	
	axis 1	axis 2	depth	Area (M2)	Volume (M3)	
MT7SUM	170	179	62	3.04	1.32	
	110	119	26	1.31	0.24	
	150	135	42	2.03	0.60	
	120	160	50	1.92	0.67	
	320	300	80	9.60	5.38	
	150	150	60	2.25	0.95	
	230	190	70	4.37	2.14	
	170	18	60	0.31	0.13	
Mean	177.5	156.4	56.3	3.1	1.43	
STDsamp	68.2	78.7	16.8	2.9	1.72	
StdError	24.1	27.8	5.9	1.0	0.61	n = 8
ALKI	150	130	40	1.95	0.55	
	175	190	73	3.33	1.70	Lb
	200	200	60	4.00	1.68	
	60	100	35	0.60	0.15	
	90	55	45	0.50	0.16	Mb
	55	65	20	0.36	0.05	
	300	160	65	4.80	2.18	
	70	55	30	0.39	0.08	Cvb
	78	55	30	0.43	0.09	
	78	68	45	0.53	0.17	
	127	148	38	1.88	0.50	
	170	165	58	2.81	1.14	
	104	137	37	1.42	0.37	
	84	100	22	0.84	0.13	
	157	165	37	2.59	0.67	
	65	70	35	0.46	0.11	
	140	150	60	2.10	0.88	
	150	170	60	2.55	1.07	
Mean	125.2	121.3	43.9	1.8	0.61	
STDsamp	62.7	50.4	15.4	0.9	0.40	
StdError	14.8	11.9	3.6	0.2	0.09	n = 18
CHATTER	165	165	53	2.72	1.01	
	100	100	35	1.00	0.25	
	200	250	35	5.00	1.23	
	310	280	45	8.68	2.73	
	400	350	40	14.00	3.92	
	450	450	50	20.25	7.09	
	500	400	100	20.00	14.00	
Mean	303.6	285.0	51.1	10.2	4.32	
STDsamp	153.2	125.5	22.6	8.0	4.85	
StdError	57.9	47.4	8.6	3.0	1.83	n = 7
E.KIDD [1]	160	190	60	3.04	1.28	
	210	200	65	4.20	1.91	
	190	150	70	2.85	1.40	
	230	250	75	5.75	3.02	
	260	250	80	6.50	3.64	
	117	130	20	1.52	0.21	
	132	105	34	1.39	0.33	
Mean	185.6	182.1	57.7	2.4	1.68	
STDsamp	52.2	56.7	22.3	0.3	1.28	
StdError	19.7	21.4	8.4	0.1	0.49	n = 7

	centimeters			square meters	cubic meters	
	axis 1	axis 2	dep;th	Area (M2)	Volume (M3)	
KASLO	120	100	30	1.20	0.25	
	165	145	40	2.39	0.67	
	165	132	35	2.18	0.53	
	180	160	15	2.88	0.30	
	70	90	30	0.63	0.13	
	70	120	35	0.84	0.21	
	50	50	25	0.25	0.04	
	200	180	40	3.60	1.01	
	300	300	150	9.00	9.45	
	234	175	35	4.10	1.00	
	430	240	72	10.32	5.20	
	450	300	70	13.50	6.62	
	250	200	75	5.00	2.63	
Mean	206.5	168.6	50.2	4.3	2.16	
STDsamp	127.2	76.4	35.4	4.1	3.02	
StdError	35.3	21.2	9.8	1.1	0.84	n = 13
WETASK	240	220	45	5.28	1.66	
	140	140	35	1.96	0.48	
	211	234	30	4.94	1.04	
	151	174	34	2.63	0.63	
	194	176	45	3.41	1.08	
	250	290	75	7.25	3.81	
	190	90	30	1.71	0.36	
	430	450	70	19.35	9.48	
	140	260	60	3.64	1.53	
Mean	216.2	226.0	47.1	5.6	2.23	
STDsamp	89.8	104.1	17.3	5.5	2.91	
StdError	29.9	34.7	5.8	1.8	0.97	n = 9
LARDEAU[2]	160	130	60	2.08	0.87	
MT7WIN[3]	89	100				
	100	120				
Mean	94.5	110.0				n = 2

[1] Stump holes mostly filled. Hard to find.

[2] One measurement of a "typical" stump hole.

[3] Stump hole size measurements not systematically recorded. Started measuring at end of this first block of the season

APPENDIX I - Summary Tables for 1992 and 1993 Surveys (% of NAR)

1992 Soil Disturbance Survey Results

Treatment Units	**Donald1**	**Donald2**	**Ch.V. TU2**	**CP3C TU3**	**Cathiness**	**Smallwood**	**CP3C TU2**	**Pinnacle**
Method	ST	ST	PO	PO	PO	PO	PO	PO
Season	summer	winter	summer	summer	summer	summer	winter	winter
Less Restrictive Defn. -Total Pot. Detrimental Dist.								
Timber Harvesting:								
R+B	0.8	1.3	0.1	4.1	0.3	3.2	2.7	1.6
H,1,3,4	2.7	2.5	6.1	4.8	7.4	4.7	3.6	5.1
proportion of M counted towards H category	*0.50*	*0.25*	*0.25*	*0.25*	*0.50*	*0.50*	*0.25*	*0.25*
% of M (NAR) added to H category	0.0	0.6	2.0	5.4	4.1	6.1	0.5	0.7
MSP:								
MSP -G	6.6	2.7	2.8	4.3	1.9	13.0	2.1	3.9
G	7.6	5.0	2.0	3.6	2.4	5.0	4.4	2.9
Total Potentially Detrimental Disturbance	**17.7**	**12.1**	**13.0**	**22.2**	**16.1**	**32.0**	**13.4**	**14.2**
Lower Confidence Interval (.9)(LCI)	2.1	5.4	2.4	4.1	3.1	3.7	2.6	3.9
Total Pot. Detrimental Disturbance - LCI(.9)	15.6	6.7	10.6	18.1	13.0	28.3	10.8	10.3
% of Total Pot. Detrimental as Timber Harvesting	20.1	36.2	63.0	64.4	73.3	43.8	51.1	51.9
% of Total Pot. Detrimental as Total MSP	79.9	63.8	37.0	35.6	26.7	56.2	48.9	48.1
% of Total Pot. Detrimental Dist. as Stump Holes	42.9	41.4	15.4	16.2	14.9	15.6	32.9	20.5
High Impact:								
C	1.5	0.2	2.3	2.0	1.4	2.0	1.3	2.3
WS	1.7	1.3	1.3	na	na	na	na	na
M	0.1	2.3	7.9	21.7	8.3	12.3	2.2	2.6
P	0.9	1.0	0.1	0.3	0.0	1.4	1.8	1.3
(B)	0.0	0.6	0.1	0.5	0.0	1.5	2.7	1.5
X	20.0	10.4	1.4	0.5	0.4	6.4	19.5	5.2
Total	**24.1**	**15.8**	**13.0**	**24.9**	**10.1**	**23.6**	**27.5**	**12.9**
Low Impact:								
OS	2.8	3.8	2.3	3.1	3.5	14.1	2.9	8.9
Other	29.6	13.6	26.5	25.1	32.1	16.0	26.6	37.2
Undisturbed:	25.8	54.8	45.2	24.6	38.3	14.4	29.6	26.9
More Restrictive Defn. -Total Pot. Detrimental Dist.								
Timber Harvesting:	3.6	4.4	8.2	14.3	11.8	14.0	6.8	7.4
MSP:								
MSP -G	6.6	2.7	2.8	4.3	1.9	13.0	2.1	3.9
G	7.6	5.0	2.0	3.6	2.4	5.0	4.4	2.9
proportion of OS counted towards ST	0.84	0.84	0.90	0.90	0.90	0.90	0.75	0.75
percentage of OS (NAR) added to ST	2.3	3.1	2.1	2.8	3.2	12.7	2.2	6.7
Total Potentially Detrimental Disturbance	**20.0**	**15.2**	**15.0**	**25.0**	**19.2**	**44.7**	**15.6**	**20.9**
Lower Confidence Interval (.9)(LCI)	2.4	5.2	2.6	4.1	3.3	3.1	2.6	4.0
Total Pot. Detrimental Disturbance - LCI(.9)	17.6	10.0	12.4	20.9	15.9	41.6	13.0	16.9
% of Total Pot. Detrimental as Timber Harvesting	17.7	28.8	54.4	57.2	61.2	31.4	43.9	35.2
% of Total Pot. Detrimental as Total MSP	82.3	71.2	45.6	42.8	38.8	68.6	56.1	64.8
% of Total Pot. Detrimental Dist. as Stump Holes	49.6	53.5	26.9	25.6	28.9	39.6	42.4	46.1
Total Soil Displacment								
Status Quo Tot.Harvesting	3.6	4.4	8.2	14.3	11.8	14.0	6.8	7.4
MSP type = VW+W+G+C+WS	17.3	9.2	8.4	9.9	5.7	20.0	7.8	9.1
OS	2.8	3.8	2.3	3.1	3.5	14.1	2.9	8.9
proportion of M counted	na	na	na	0.5	na	0.5	na	na
% M	na	na	na	10.8	na	6.1	na	na
Total Soil Displacment	**23.7**	**17.3**	**18.8**	**38.6**	**21.0**	**54.7**	**17.6**	**25.4**
LCI (0.9)	2.7	6.3	3.0	4.0	3.5	3.7	2.8	4.2

Treatment Units	Donald1	Donald2	Ch.V. TU2	CP3C TU3	Cathiness	Smallwood	CP3C TU2	Pinnacle
Method	**summer Stumped (n=1)**		**winter Stumped (n=1)**		**summer PO (n=4)**		**winter PO (n=2)**	
	mean	SEm	mean	SEm	mean	SEm	mean	SEm
Less Restrictive Defn. - Total Pot. Detrimental Dist.								
Timber Harvesting:								
R+B	0.8	na	1.3	na	1.9	1.0	2.1	0.5
H,1,3,4	2.7	na	2.5	na	5.8	0.6	4.4	0.7
proportion of M counted towards H category								
% of M (NAR) added to H category	0.0	na	0.6	na	4.4	0.9	0.6	0.1
MSP:								
MSP -G	6.6	na	2.7	na	5.5	2.5	3.0	0.9
G	7.6	na	5.0	na	3.3	0.7	3.7	0.7
Total Potentially Detrimental Disturbance	**17.7**	**na**	**12.1**	**na**	**20.8**	**4.2**	**13.8**	**0.4**
Lower Confidence Interval (.9)(LCI)	2.1	na	5.4	na	3.3	0.4	3.3	0.7
Total Pot. Detrimental Disturbance - LCI(.9)	15.6	na	6.7	na	17.5	3.9	10.5	0.3
% of Total Pot. Detrimental as Timber Harvesting	20.1	na	36.2	na	61.1	6.2	51.5	0.4
% of Total Pot. Detrimental as Total MSP	79.9	na	63.8	na	38.9	6.2	48.5	0.4
% of Total Pot. Detrimental Dist. as Stump Holes	42.9	na	41.4	na	15.5	0.3	26.7	6.2
High Impact:								
C	1.5	na	0.2	na	1.9	0.2	1.8	0.5
WS	1.7	na	1.3	na	1.3	na	na	na
M	0.1	na	2.3	na	12.5	3.2	2.4	0.2
P	0.9	na	1.0	na	0.4	0.3	1.6	0.3
(B)	0.0	na	0.6	na	0.5	0.3	2.1	0.6
X	20.0	na	10.4	na	2.2	1.4	12.3	7.2
Total	24.1	na	15.8	na	17.9	3.7	20.2	7.3
Low Impact:								
OS	2.8	na	3.8	na	5.7	2.8	5.9	3.0
Other	29.6	na	13.6	na	24.9	3.3	31.9	5.3
Undisturbed:	25.8	na	54.8	na	30.6	6.9	28.3	1.3
More Restrictive Defn. -Total Pot. Detrimental Dist.								
Timber Harvesting:	3.6	na	4.4	na				
MSP:								
MSP -G	6.6	na	2.7	na	5.5	2.5	3.0	0.9
G	7.6	na	5.0	na	3.3	0.7	3.7	0.7
proportion of OS counted towards ST	0.8	na	0.8	na				
percentage of OS (NAR) added to ST	2.3	na	3.1	na	5.2	2.5	4.5	2.2
Total Potentially Detrimental Disturbance	**20.0**	**na**	**15.2**	**na**	**26.0**	**6.6**	**18.2**	**2.6**
Lower Confidence Interval (.9)(LCI)	2.4	na	5.2	na	3.3	0.3	3.3	0.7
Total Pot. Detrimental Disturbance - LCI(.9)	17.6	na	10.0	na	22.7	6.5	14.9	2.0
% of Total Pot. Detrimental as Timber Harvesting	17.7	na	28.8	na	51.1	6.7	39.5	4.3
% of Total Pot. Detrimental as Total MSP	82.3	na	71.2	na	48.9	6.7	60.5	4.3
% of Total Pot. Detrimental Dist. as Stump Holes	49.6	na	53.5	na	30.3	3.2	44.2	1.8
Total Soil Displacment								
Status Quo Tot.Harvesting	3.6	na	4.4	na	12.1	1.4	7.1	0.3
MSP type = VW+W+G+C+WS	17.3	na	9.2	na	11.0	3.1	8.5	0.6
OS	2.8	na	3.8	na	5.7	2.8	5.9	3.0
proportion of M counted								
% M	na	na	na	na	8.5	1.7	na	na
Total Soil Displacment	23.7	na	17.3	na	33.3	8.4	21.5	3.9
LCI (0.9)	2.7	na	6.3	na	3.5	0.2	3.5	0.7

1993 Soil Disturbance Surveys

Site	**Wetask**	**Chatter**	**Kaslo**	**E.Kidd**	**ChrisV**	**Colepitts**	**Mt7S**	**Mt7W**	**Alki**	**Slewiskin**	**Lardeau**
Method	ST	ST	ST	PO	PO	PO	PO	PO	PO	PO	PO
Season	summer	winter	winter	summer	summer	summer	summer	winter	winter	winter	winter
Less Restrictive Definition of Potentially Det. Disturbance											
Timber Harvesting:											
Skid Rd.	0.1	2.6	1.3	3.6	0.0	0.0	13.7	0.1	1.7	1.7	0.0
Hc,Tc,Ic	2.8	2.1	1.4	9.7	4.7	10.5	7.4	2.6	0.8	2.0	1.7
MSP											
MSP-G(=WG,LG,VW,WS,G2+STWG,G2+STWG/D)	11.7	6.1	10.6	12.9	1.3	8.1	12.7	5.8	3.2	1.9	3.9
G(=G,G/D,GWG,GWG/D)	7.3	3.9	4.3	0.6	0.7	1.2	2.5	0.8	0.9	7.3	1.4
Total Potentially Detrimental Disturbance	22.0	14.7	17.3	26.9	6.7	19.8	36.3	9.2	6.6	12.9	7.0
LCI(.9)	3.0	1.9	2.5	6.1	2.0	3.4	4.3	1.3	1.3	1.6	1.3
Total Pot. Detrimental Disturbance - LCI(.9)	19.0	12.8	14.8	20.8	4.7	16.4	32.0	7.9	5.3	11.3	5.7
% of Total Pot. Detrimental Disturbance as Timber Harvesting	13.6	32.0	15.1	49.6	70.2	53.1	58.1	28.6	38.0	28.9	24.1
% of Total Pot. Detrimental Disturbance as total MSP	86.4	68.0	85.9	50.4	29.8	46.9	41.9	71.4	62.0	71.1	75.9
Stump Holes as % of Total Pot. Detrimental Disturbance	33.2	26.4	24.8	2.4	10.4	6.1	6.9	8.7	13.6	56.4	20.0
High Impact											
G2	2.0	2.0	2.1	1.6	1.4	1.8	3.1	2.6	1.5	3.5	1.3
ST	3.1	5.1	3.4	1.7	2.6	2.0	2.3	2.7	2.5	7.1	2.4
Other MSP Cat.	0.0	0.3	0.4	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.6
H,I,TE	0.3	1.8	2.0	1.7	1.4	1.0	1.8	2.3	0.7	0.2	0.2
MX/F1&2c	1.2	0.3	0.4	1.5	1.6	2.6	1.2	1.4	0.1	2.7	1.3
P	0.0	2.1	1.2	0.1	0.0	0.0	2.0	0.3	3.3	0.4	3.9
Total	6.6	11.5	9.4	6.6	6.9	7.4	10.8	9.3	8.1	13.9	9.8
LCI(.9)	0.8	1.5	1.1	0.9	1.5	1.1	1.8	1.4	1.3	1.7	1.8
Low Impact (includes G2/D + ST/D)	54.2	54.1	46.6	60.1	62.5	61.2	47.2	69.2	57.2	67.2	59.4
Undisturbed	17.2	19.8	26.7	6.5	24.0	11.5	5.7	12.3	28.0	6.0	23.8

Site	**Wetask**	**Chatter**	**Kaslo**	**E.Kidd**	**ChrisV**	**Colepitts**	**Mt7S**	**Mt7W**	**Alki**	**Slewiskin**	**Lardeau**
Method	ST	ST	ST	PO	PO	PO	PO	PO	PO	PO	PO
Season	summer	winter	winter	summer	summer	summer	summer	winter	winter	winter	winter
More Restrictive Defn. - Total Pot. Detrimental Disturbance											
Timber Harvesting											
Skid Rd.s	0.1	2.6	1.3	3.6	0.0	0.0	13.7	0.1	1.7	1.7	0.0
H,T,Ic	2.8	2.1	1.4	9.7	4.7	10.5	7.4	2.6	0.8	2.0	1.7
MSP											
MSP(-G)	5.3	3.5	7.5	10.4	0.9	4.2	7.4	1.8	0.8	2.5	0.3
G(=G,G2,ST+G,G2,ST/WG+G,G2,ST/WG/D)	17.2	13.3	12.7	6.4	4.9	8.7	13.0	9.8	7.3	16.8	8.2
Total	25.5	21.5	22.8	30.2	10.5	23.4	41.5	14.3	10.7	23.0	10.2
LCI(.9)	3.0	2.2	3.0	6.1	1.9	3.3	4.1	1.3	1.7	1.7	1.4
Total Pot. Detrimental Disturbance - LCI(.9)	22.5	19.3	19.8	24.1	8.6	20.1	37.4	12.9	9.0	21.3	8.8
% of Total Pot. Detrimental Disturbance as Timber Harvesting	11.7	21.8	11.5	44.1	45.1	44.9	50.8	18.6	23.7	16.3	16.5
% of Total Pot. Detrimental Disturbance as total MSP	88.3	78.2	88.5	55.9	54.9	55.1	49.2	81.4	76.3	83.7	83.5
% of Total Pot. Detrimental Disturbance as Stump Holes	67.3	61.8	55.6	21.3	46.7	37.3	31.3	68.8	68.7	72.9	80.2
High Impact											
Other MSP Cat.	0.0	0.3	0.4	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.6
H,I,TE	0.3	1.8	2.0	1.7	1.4	1.0	1.8	2.3	0.7	0.2	0.2
MX/F1&2c	1.2	0.3	0.4	1.5	1.6	2.6	1.2	1.4	0.1	2.7	1.3
P	0.0	2.1	1.2	0.1	0.0	0.0	2.0	0.3	3.3	0.4	3.9
Total	1.5	4.4	3.9	3.3	2.9	3.7	5.4	4.0	4.1	3.3	6.1
LCI(.9)	0.8	1.8	1.0	0.8	1.3	1.2	1.7	1.3	1.3	1.0	1.7
Low Impact (includes G,G2,ST/D)	55.8	54.2	46.5	60.1	62.6	61.4	47.4	68.7	57.2	67.7	59.8
Undisturbed	17.2	19.9	26.7	6.5	24.0	11.5	5.7	12.3	28.0	6.0	23.8
Total Soil Displacement											
MSP+Other+G2+ST	25.0	17.6	21.4	17.2	6.0	13.3	21.0	11.9	8.3	20.8	9.7
Pot.Det.Harvesting:R,H,I,Tc	3.0	4.7	2.6	13.3	4.7	10.5	21.1	2.6	2.5	3.7	1.7
Harvesting Scalps:HE,IE,TE,ME,MEc,LE,LEc,OS	3.4	6.6	6.1	9.5	3.8	3.6	5.6	12.8	2.4	8.8	3.6
Total	31.4	28.9	30.1	40.0	14.5	27.4	47.7	27.4	13.1	33.4	15.0
LCI(.9)	3.2	2.6	3.0	5.2	2.4	3.5	4.1	2.7	1.7	2.3	2.1

	summer Stumped (n = 1)		winter Stumped (n=2)		summer PO (n=4)		winter PO (n=4)	
	mean	SEm	mean	SEm	mean	SEm	mean	SEm
Less Restrictive Definition of Potentially Det. Disturbance								
Timber Harvesting								
Skid Rd.	0.1	na	1.9	0.7	4.3	3.2	0.9	0.5
Hc,Tc,Ic	2.8	na	1.7	0.3	8.1	1.3	1.8	0.4
MSP								
MSP-G(=WG,LG,VW,WS,G2+STWG,G2+STWG/D)	11.7	na	8.3	2.2	8.8	2.7	3.7	0.8
G(=G,G/D,GWG,GWG/D)	7.3	na	4.1	0.2	1.3	0.4	2.6	0.4
Total Potentially Detrimental Disturbance	22.0	na	16.0	1.3	22.4	6.2	9.0	1.5
LCI(.9)	3.0	na	2.2	0.3	3.9	0.9	1.4	0.1
Total Pot. Detrimental Disturbance - LCI(.9)	19.0	na	13.8	1.0	18.5	5.6	7.6	1.4
% of Total Pot. Detrimental Disturbance as Timber Harvesting	13.6	na	23.6	8.5	57.7	4.5	29.9	2.9
% of Total Pot. Detrimental Disturbance as total MSP	86.4	na	76.9	9.0	42.3	4.5	70.1	2.9
Stump Holes as % of Total Pot. Detrimental Disturbance	33.2	na	25.6	0.8	6.4	1.7	24.7	10.8
High Impact								
G2	2.0	na	2.0	0.1	2.0	0.4	2.2	0.5
ST	3.1	na	4.2	0.9	2.2	0.2	3.7	1.1
Other MSP Cat.	0.0	na	0.3	0.0	0.1	0.1	0.1	0.1
H,I,TE	0.3	na	1.9	0.1	1.5	0.2	0.8	0.4
MX/F1&2c	1.2	na	0.4	0.1	1.7	0.3	1.4	0.5
P	0.0	na	1.6	0.4	0.5	0.5	2.0	1.0
Total	6.6	na	10.4	1.0	7.9	1.0	10.3	1.3
LCI(.9)	0.8	na	1.3	0.2	1.3	0.2	1.6	0.1
Low Impact (includes G2/D + ST/D)	54.2	na	50.3	3.7	57.7	3.5	63.3	2.9
Undisturbed	17.2	na	23.2	3.5	11.9	4.2	17.5	5.1
More Restrictive Defn. - Total Pot. Detrimental Disturbance								
Timber Harvesting								
Skid Rd.s	0.1	na	1.9	0.7	4.3	3.2	0.9	0.5
H,T,Ic	2.8	na	1.7	0.3	8.1	1.3	1.8	0.4
MSP								
MSP(-G)	5.3	na	5.5	2.0	5.7	2.1	1.4	0.5
G(=G,G2,ST+G,G2,ST/WG+G,G2,ST/WG/D)	17.2	na	13.0	0.3	8.3	1.8	10.5	2.1
Total	25.5	na	22.2	0.6	26.4	6.5	14.5	3.0
LCI(.9)	3.0	na	2.6	0.4	3.8	0.9	1.5	0.1
Total Pot. Detrimental Disturbance - LCI(.9)	22.5	na	19.6	0.2	22.5	5.9	13.0	2.9
% of Total Pot. Detrimental Disturbance as Timber Harvesting	11.7	na	16.7	5.2	46.2	1.5	18.7	1.7
% of Total Pot. Detrimental Disturbance as total MSP	88.3	na	83.3	5.2	53.8	1.5	81.3	1.7
% of Total Pot. Detrimental Disturbance as Stump Holes	67.3	na	58.7	3.1	34.2	5.3	72.6	2.7
High Impact								
Other MSP Cat.	0.0	na	0.3	0.0	0.1	0.1	0.1	0.1
H,I,TE	0.3	na	1.9	0.1	1.5	0.2	0.8	0.5
MX/F1&2c	1.2	na	0.4	0.1	1.7	0.3	1.4	0.5
P	0.0	na	1.6	0.4	0.5	0.5	2.0	1.0
Total	1.5	na	4.2	0.2	3.8	0.6	4.4	0.6
LCI(.9)	0.8	na	1.4	0.4	1.2	0.2	1.3	0.1
Low Impact (includes G,G2,ST/D)	55.8	na	50.4	3.8	57.9	3.5	63.4	2.8
Undisturbed	17.2	na	23.3	3.4	11.9	4.2	17.5	5.1
Total Soil Displacement								
MSP+Other+G2+ST	25.0	na	19.5	1.9	14.4	3.2	12.7	2.8
Pot.Det.Harvesting:R,H,I,Tc	3.0	na	3.7	1.0	12.4	3.4	2.6	0.4
Harvesting Scalps:HE,IE,TE,ME,MEc,LE,LEc,OS	3.4	na	6.3	0.2	5.6	1.4	6.9	2.4
Total	31.4	na	29.5	0.6	32.4	7.3	22.2	4.9
LCI(.9)	3.2	na	2.8	0.2	3.8	0.6	2.2	4.9

Slope Classes
1: 0 -1
2: 6 - 15
3: 16 - 30
4: 31 - 45
5: 46 - 70
6: 70 - 100

Equipment Codes
ls = line skidder
gs = grapple skidder
rts = rubber tired skidder
sc = small cat
ex = excavator
fb = feller - buncher
D4H = high drive small
caterpillar

Silviculture System
cc=clear cut
str=single tree retention

Skidding Pattern
rsk=random skidding
dsk=designated skidding

MSP Counted Disturbances
"P"=G,W,VW,LG = deep gouge, wide gouge, very wide scalp, long gouge
WS=wide scalp
C=continuous scalp

Leading Soil Disturbance Hazards
Types:
E=erosion
Mw=mass wasting
C=compaction
D=displacement

Ratings:
H=high
M=moderate
L=low

Less Restrictive Defn.
Pot. Detrimental=
MSP, R,HEc,HFc,TEc,IEc,IFc
e.g., MSP = G1,LG,WS,VWS
High Impact =
G2,ST,CG,HE,IE,TE,M1&2c,P
Low Impact = G1,G2,ST/D, all others
Low Impact = G1,G2,ST/D, all others

More Restrictive Defn.
Pot. Detrimental=
G1,G2,ST,(G1,G2,ST-WG;G1,G2,ST/D-WG),WG,LG,VWS,WS,R,HEc,HFc,TEc,IEc,IFc
High Impact=
HE,TE,IT,M1&2c,P
Low Impact=G1,G2,ST/D, all others

Displacement
Harsting Pot. Det., all MSP, HE,TE,IE;ME1c,ME1,ME2c,ME,LE,LEc,OS

APPENDIX J - Data Summary Tables

1993 Surveys

Table 1. Per cent of NAR as stump holes

Season	S	W	W	S	S	S	S	W	W	W	W	S+W	S+W	S	S	W	W
System	ST	ST	ST	PO	PO	PO	PO	PO	PO	PO	PO	ST	ST	PO	PO	PO	PO
Skidding Pattern	R	D	R	R	R	D	D	R+D	R+D	R	D						
Site	Wetask	Chatter	Kaslo	E.Kidd	Ch.V.	Colepitts	Mt.7s	Mt.7w	Alki	Slewiskin	Lardeau	Mean	SEm	Mean	SEm	Mean	SEm
G1	9.9	4.6	4.0	2.5	0.9	3.7	7.0	4.8	2.7	6.6	4.5	6.2	1.9	3.5	2.6	5.0	0.8
G2	3.3	3.2	2.4	1.5	1.4	2.1	3.3	2.6	1.6	3.5	1.3	2.9	0.3	2.1	0.9	2.4	0.5
ST	6.4	5.7	7.4	2.5	2.8	3.4	2.9	2.8	3.2	8.2	2.9	6.5	0.5	2.9	0.4	4.7	1.3
Total	19.6	13.5	13.8	6.5	5.1	9.2	13.2	10.1	7.4	18.3	8.8	15.7	2.0	8.5	3.6	12.1	2.4

R=random; D=designated

Table 2. Per cent of NAR as stump holes meeting the wide gouge criteria

Season	S	W	W	S	S	S	S	W	W	W	W	S+W	S+W	S	S	W	W
System	ST	ST	ST	PO	PO	PO	PO	PO	PO	PO	PO	ST	ST	PO	PO	PO	PO
Skidding Pattern	R	D	R	R	R	D	D	R+D	R+D	R	D						
Site	Wetask	Chatter	Kaslo	E.Kidd	Ch.V.	Colepitts	Mt.7s	Mt.7w	Alki	Slewiskin	Lardeau	Mean	SEm	Mean	SEm	Mean	SEm
G1	7.8	3.8	3.2	2.5	0.9	3.5	6.5	4.8	2.5	6.6	4.3	4.9	1.4	3.4	2.4	4.6	0.9
G2	2.2	2.4	2.0	1.5	1.4	1.9	3.2	2.6	1.5	3.5	1.3	2.2	0.1	2.0	0.8	2.2	0.5
ST	3.8	3.7	5.5	1.9	2.6	2.1	2.3	1.6	2.6	8.1	2.5	4.3	0.6	2.2	0.3	3.8	1.5
G1WG	2.1	0.9	0.8	0.0	0.0	0.1	0.5	0.0	0.2	0.0	0.2	1.3	0.4	0.2	0.2	0.3	0.1
G2WG	1.1	0.7	0.4	0.0	0.0	0.2	0.1	0.0	0.2	0.0	0.2	1.3	0.4	0.2	0.2	0.3	0.1
STWG	2.6	2.0	2.0	0.6	0.2	1.3	0.6	1.2	0.6	0.1	0.4	2.2	0.2	0.7	0.5	0.9	0.2
Tot % of NAR	19.6	13.5	13.8	6.5	5.1	9.2	13.2	10.1	7.4	18.3	8.8	15.7	2.0	8.5	3.6	12.1	2.4
%of stump holes vs categories																	
G1	39.8	27.8	23.4	38.3	18.0	38.5	49.1	47.1	33.3	36.2	48.7	30.3	4.9	36.0	13.0	39.1	3.9
G2	11.2	18.1	14.2	23.4	27.0	21.0	23.9	25.5	20.2	19.1	15.4	14.5	2.0	23.8	2.5	18.9	2.1
ST	19.3	27.3	39.7	28.7	51.7	23.1	17.4	15.9	34.4	44.3	28.2	28.8	5.9	30.2	15.0	30.3	5.9
G1WG	10.8	6.6	5.7	0.0	0.0	1.4	3.9	0.0	2.7	0.0	2.6	7.7	1.6	1.3	1.8	2.6	0.8
G2WO	5.6	5.3	2.8	0.0	0.0	2.1	0.9	0.0	1.1	0.0	0.0	4.6	0.9	0.7	1.0	1.1	0.3
STWG	13.4	15.0	14.2	9.6	3.4	14.0	4.8	11.5	8.2	0.4	5.1	14.2	0.5	7.9	4.8	7.9	2.3
%of stump holes meeting the WG criteria	29.7	26.9	22.7	9.6	3.4	17.5	9.6	11.5	12.0	0.4	7.7	26.4	2.0	10.0	5.8	11.6	2.7

Table 3. Per cent of NAR as stump holes and stump holes with deposits & of stump holes filled with mineral deposits

Season	S	W	W	S	S	S	S	W	W	W	W	S+W	S+W	S	S	W	W
System	ST	ST	ST	PO	PO	PO	PO	PO	PO	PO	PO	ST	ST	PO	PO	PO	PO
Skidding Pattern	R	D	R	R	R	D	D	R+D	R+D	R	D						
Site	Wetask	Chatter	Kaslo	E.Kidd	Ch.V.	Colepitts	Mt.7s	Mt.7w	Alki	Slewiskin	Lardeau	Mean	SEm	Mean	SEm	Mean	SEm
G1,G2,ST	5.3	9.7	9.9	1.4	2.3	2.8	2.9	1.9	2.1	3.1	3.1	8.3	1.5	2.4	0.7	3.7	0.3
G1,G2,ST+D1	2.1	0.2	0.6	0.2	0.5	0.4	1.0	0.3	0.4	1.6	0.1	1.0	0.6	0.5	0.4	0.7	0.3
G1+G2+ST+D2	3.4	1.2	0.5	0.6	0.3	0.8	0.9	0.5	0.4	1.4	0.6	1.7	0.9	0.6	0.2	0.9	0.2
G1+G2+ST+D3	2.6	0.6	0.2	0.1	0.2	0.4	0.2	0.3	0.1	0.6	0.6	1.1	0.8	0.2	0.1	0.5	0.1
G1+G2+ST+X1+2	3.9	1.2	1.7	2.6	1.6	2.9	4.2	2.2	3.0	8.9	3.3	2.2	0.8	2.8	1.1	3.9	1.5
G1+G2+ST+X3	2.3	0.6	0.5	0.9	0.1	0.7	2.8	4.2	0.7	2.0	1.0	1.1	0.6	1.1	1.1	1.8	0.8
G1+G2+ST+B1+2	0.1	0.0	0.4	0.6	0.1	1.0	1.3	0.8	0.7	0.8	0.0	0.2	0.1	0.7	0.5	0.5	0.2
G1+G2+ST+B3	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total	19.6	13.5	13.8	6.5	5.1	9.2	13.2	10.1	7.4	18.3	8.8	15.7	2.0	8.5	3.6	12.1	2.4
%D1,2,3	41.3	15.0	9.2	13.8	19.1	18.1	16.1	10.8	12.0	19.6	14.1	21.8	9.9	16.8	2.3	15.7	1.9
%D2	17.1	8.8	3.5	8.5	6.7	9.1	6.5	4.5	4.9	7.7	6.4	9.8	3.9	7.7	1.3	6.7	0.7
%D3	13.4	4.4	1.4	2.1	3.4	4.2	1.7	3.2	1.1	3.4	6.4	6.4	3.6	2.9	1.1	4.1	1.1
Total% D2+D3	30.5	13.2	5.0	10.6	10.1	13.3	8.3	7.6	6.0	11.1	12.8	16.2	7.5	10.6	2.1	10.8	1.6

D = mineral deposits & X = woody deposits: 1 (<15 cm), 2 (15-30cm), 3 (>15 cm); B = brush piles: 1 (<30 cm); 2 (30-80cm), 3 (>80cm)

Table 4. Distribution of mineral deposits versus depth and compaction (% of NAR)

Season	S	W	W	S	S	S	S	W	W	W	W	S+W	S+W	S	S	W	W
System	ST	ST	ST	PO	PO	PO	PO	PO	PO	PO	PO	ST	ST	PO	PO	PO	PO
Skidding Pattern	R	D	R	R	R	D	D	R+D	R+D	R	D						
Site	Wetask	Chatter	Kaslo	E Kidd	Ch.V	Colepitts	Mt.7s	Mt.7w	Alki	Slewiskin	Lardeau	Mean	SEm	Mean	SEm	Mean	SEm
D3c	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D2c	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
D1c	0.1	0.1	0.0	0.0	0.0	1.0	0.2	0.0	0.1	0.1	0.0	0.1	0.0	0.3	0.5	0.0	0.0
D3	4.6	3.5	0.9	0.5	0.3	0.6	0.6	0.6	0.2	1.8	1.0	3.0	1.1	0.5	0.2	1.3	0.3
D2	6.5	4.9	2.8	2.5	0.8	2.6	2.2	2.5	0.8	4.4	1.7	4.8	1.1	2.0	0.8	2.8	0.8
D1	5.9	3.5	2.7	3.5	4.0	6.6	5.1	5.2	1.9	7.4	3.1	4.0	1.0	4.8	1.4	4.3	1.2
Tot	17.2	11.9	6.5	6.7	5.1	11.0	8.1	8.2	3.0	13.7	5.8	11.8	3.1	7.7	2.5	8.5	2.3
% of mineral deposits occuring in stump holes	65	15	17	8	19	16	23	10	3	25	17						

deposit 1 = <15 cm; 2= 15-30cm; 3= >30 cm. c refers to compaction

Table 5. Per cent of deep deposits (D3) occurring over other disturbances

Season	S	W	W	S	S	S	S	W	W	W	W
System	ST	ST	ST	PO	PO	PO	PO	PO	PO	PO	PO
Skidding Pattern	R	D	R	R	R	D	D	R+D	R+D	R	D
Site	Wetask	Chatter	Kaslo	E.Kidd	Ch.V	Colepitts	Mt.7s	Mt.7w	Alki	Slewiskin	Lardeau
G	59	22	22	22	60	67	44	44	40	36	63
WS											
LG											
WO	5		5								
H											
Hc											
M											
Mc											
U	23	78	69	44	40	22	33	22	60	41	38
L	10		3	33		11	22	33		23	
Lc	3										

Table 6. Distribution of woody debris deposits versus depth and compaction (% of NAR) & per cent of woody debris deposits overlying other disturbances

Season	S	W	W	S	S	S	S	W	W	W	W	S+W	S+W	S	S	W	W
System	ST	ST	ST	PO	PO	PO	PO	PO	PO	PO	PO	ST	ST	PO	PO	PO	PO
Skidding Pattern	R	D	R	R	R	D	D	R+D	R+D	R	D						
Site	Wetask	Chatter	Kaslo	E.Kidd	Ch.V.	Colepitts	Mt.7s	Mt.7w	Alki	Slewiskin	Lardeau	Mean	SEm	Mean	SEm	Mean	SEm
X3crib	0.0	0.2	0.0	0.4	0.0	0.2	0.3	1.5	0.2	0.2	0.0	0.1	0.1	0.2	0.2	0.4	0.3
X2crib	0.1	0.4	0.0	0.7	0.1	0.3	0.5	0.7	0.5	0.3	0.0	0.2	0.1	0.4	0.3	0.3	0.2
X1crib	0.3	0.3	0.0	0.4	0.6	1.0	0.4	0.4	0.5	0.4	0.0	0.2	0.1	0.6	0.3	0.3	0.1
X3	7.1	3.9	1.9	3.0	0.4	2.7	7.2	7.5	1.5	4.4	2.0	4.3	1.5	3.3	2.8	4.0	1.4
X2	9.1	7.7	3.3	7.4	2.3	6.0	12.0	14.3	6.5	13.4	4.8	6.7	1.7	6.9	4.0	9.2	2.4
X1	14.8	9.0	7.5	22.6	13.7	20.8	21.6	21.8	13.4	26.1	13.9	10.4	2.2	19.7	4.0	17.1	3.1
Tot	31.4	21.5	12.7	34.5	17.1	31.0	41.9	46.1	22.7	44.9	20.8	21.9	5.4	31.1	10.4	31.3	5.9
% of X overlying other disturbances																	
G	20	15	4	11	11	11	17	15	3	24	20						
H	2	12	0	9	7	10	13	12	4	1	5						
M	4	4	1	17	9	16	13	12	2	7	16						
Other	74	69	95	64	73	64	56	61	91	68	59						

deposit 1 = <15 cm; 2= 15-30cm; 3= >30 cm; crib refers to cribbed

Table 7. Per cent of NAR occupied by brush piles

Season	S	W	W	S	S	S	S	W	W	W	W	S-W	S+ W	S	S	W	W
System	ST	ST	ST	PO	PO	PO	PO	PO	PO	PO	PO	ST	ST	PO	PO	PO	PO
Skidding Pattern	R	D	R	R	R	D	D	R+D	R+D	R	D						
Site	Wetask	Chatter	Kaslo	E.Kidd	Ch.V.	Colepitts	Mt.7s	Mt.7w	Alki	Slewiskin	Lardeau	Mean	SEm	Mean	SEm	Mean	SEm
B3crib	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
B2crib	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
B1crib	0.0	0.3	0.0	0.7	0.0	0.4	0.1	0.0	0.5	0.2	0.0	0.1	0.1	0.3	0.3	0.1	0.1
B3	0.1	0.0	0.5	0.2	0.0	0.3	0.1	0.0	0.9	0.0	0.4	0.2	0.1	0.1	0.1	0.3	0.2
B2	1.2	0.5	2.0	1.3	0.1	2.0	2.2	1.2	3.6	1.1	2.5	1.2	0.4	1.4	1.0	1.9	0.6
B1	2.3	0.9	3.9	4.4	0.0	6.3	7.0	3.1	8.7	1.7	3.6	2.4	0.9	4.4	3.1	3.9	1.5
Tot	3.7	1.8	6.4	6.7	0.1	9.2	9.3	4.3	14.2	3.0	6.5	3.9	1.3	6.3	4.3	6.4	2.5

deposit 1 = <30 cm; 2= 30-70cm: 3= >70 cm; crib refers to cribbed & compacted

Table 8. Light disturbances (% of NAR)

Season	S	W	W	S	S	S	S	W	W	W	W	S+W	S+W	S	S	W	W
System	ST	ST	ST	PO	PO	PO	PO	PO	PO	PO	PO	ST	ST	PO	PO	PO	PO
Skidding Pattern	R	D	R	R	R	D	D	R+D	R+D	R	D						
Site	Wetask	Chatter	Kaslo	E.Kidd	Ch.V.	Colpitts	Mt.7s	Mt.7w	Alki	Slewiskin	Lardeau	Mean	SEm	Mean	SEm	Mean	SEm
LE	4.7	4.0	4.2	8.9	2.8	4.1	5.5	5.7	1.9	8.6	1.8	4.3	0.2	5.3	2.6	4.4	1.6
LF	28.2	15.7	26.4	31.1	41.7	38.1	23.6	34.6	28.8	39.7	30.0	23.4	3.9	33.6	8.0	31.3	2.5
LEc	0.4	0.4	0.1	0.7	0.6	0.3	0.2	0.3	0.0	0.9	0.0	0.3	0.1	0.4	0.2	0.3	0.2
LFc	2.3	0.6	1.3	0.9	2.5	1.2	0.1	2.3	0.1	2.0	0.2	1.4	0.5	1.2	1.0	1.2	0.6
Total	35.6	20.7	32.0	41.5	47.6	43.7	29.4	42.8	30.8	51.2	32.1	29.4	4.5	40.6	7.9	37.3	4.8

E = point scalped; F = forest floor intact; c = compacted